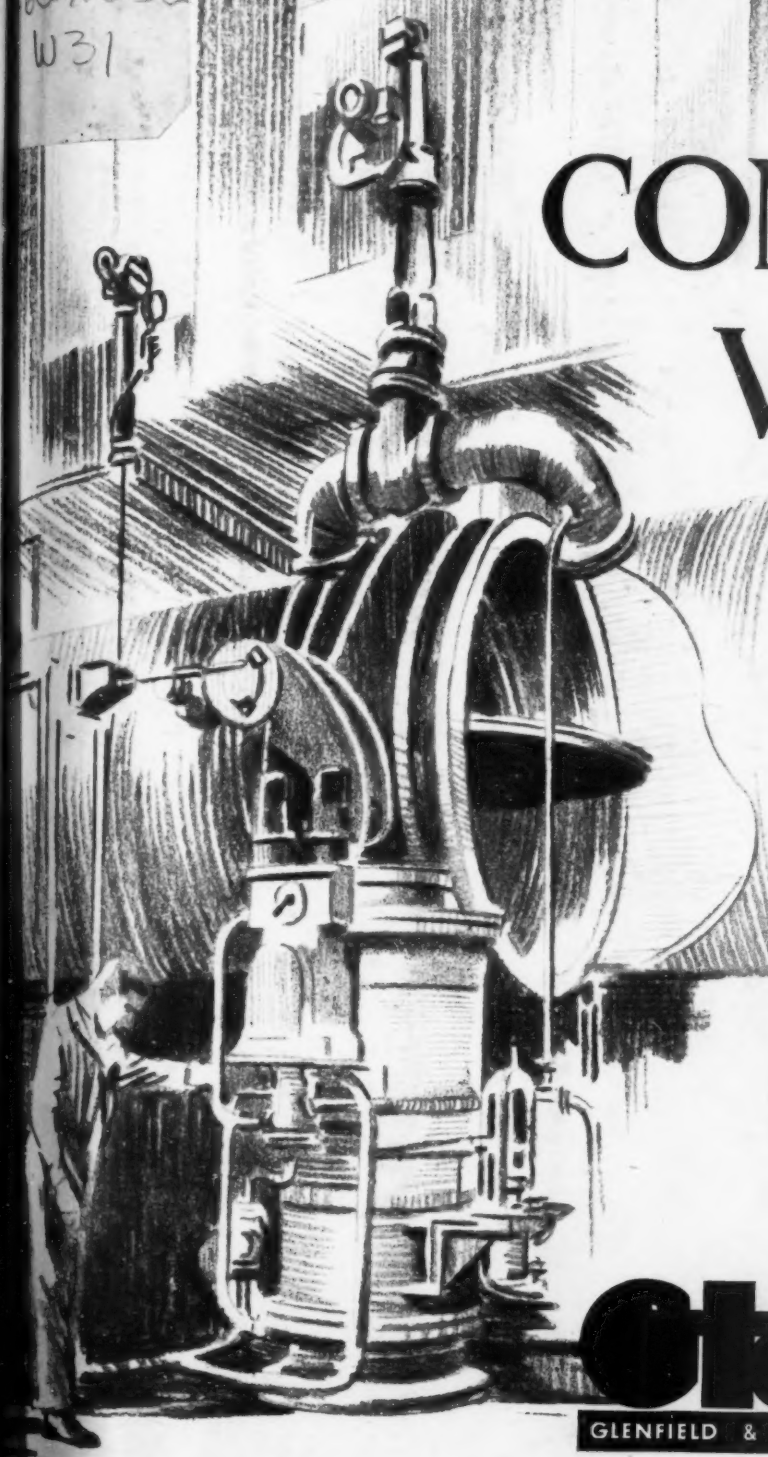
Water Power

INTERNATIONAL DEVELOPMENT OF HYDRO-ELECTRIC POWER

AUGUST 1951

627.052
W31



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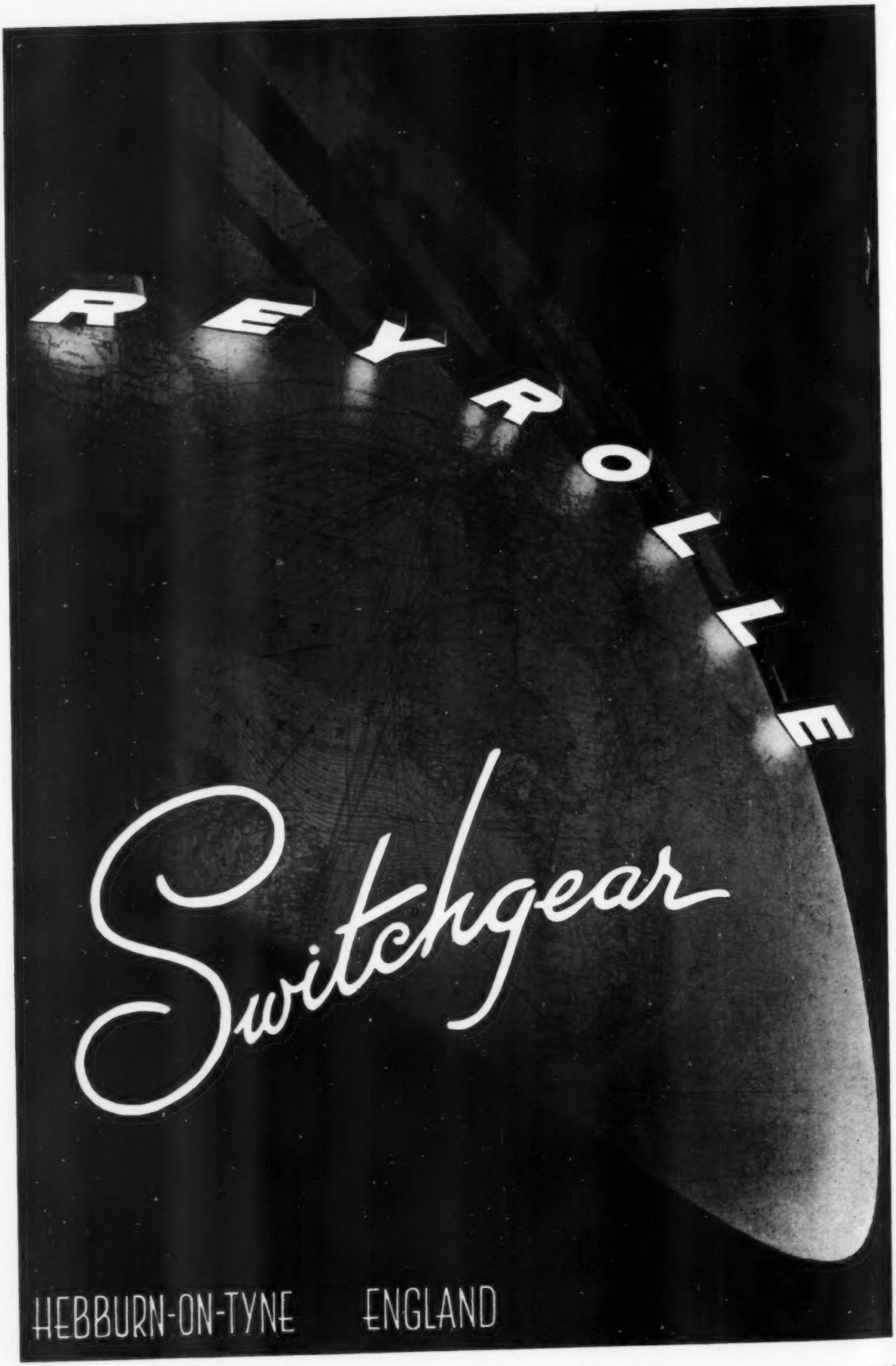
CONTROL VALVES
for HYDRO-ELECTRIC PIPELINES and DAMS

Glenfield

GLENFIELD & KENNEDY, LIMITED, KILMARNOCK.


REYROLLE
Switchgear
HEBBURN-ON-TYNE ENGLAND

'ENGLISH ELECTRIC'

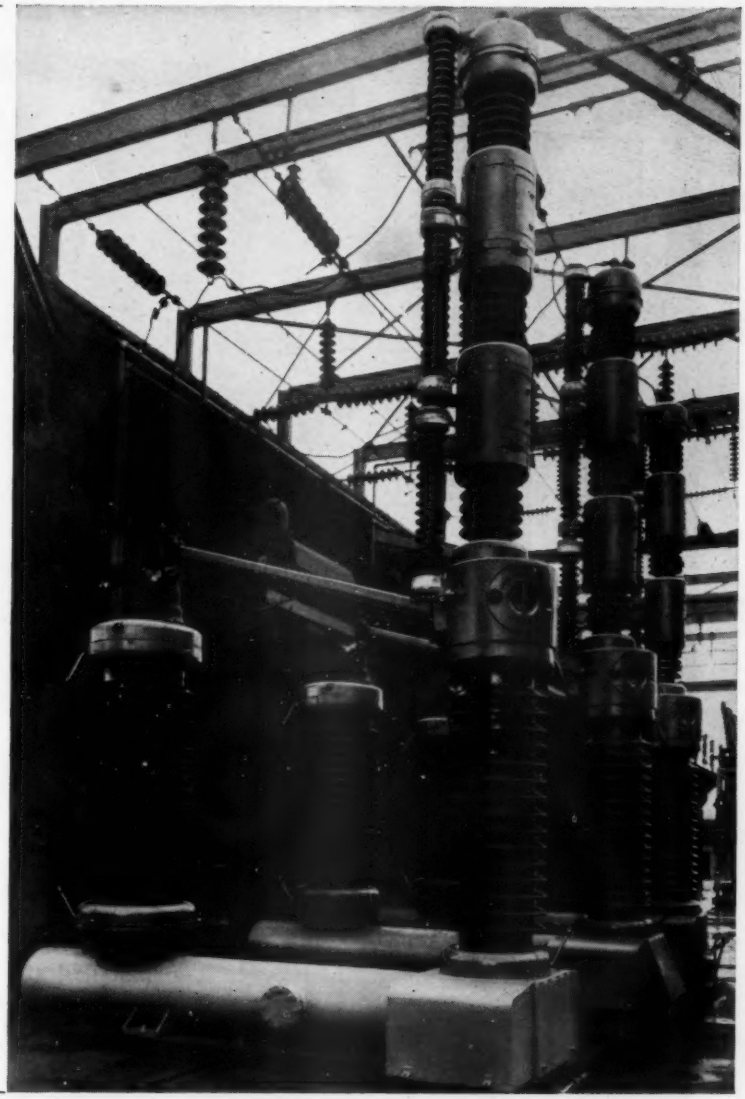
switchgear

High voltage air-blast circuit-breakers for outdoor service

Tested for breaking charging currents of long lines

•

Illustrated is a 165-kV, 3,500-MVA air-blast circuit-breaker recently tested for breaking line charging currents at Fontenay, France.



The ENGLISH ELECTRIC Company Limited

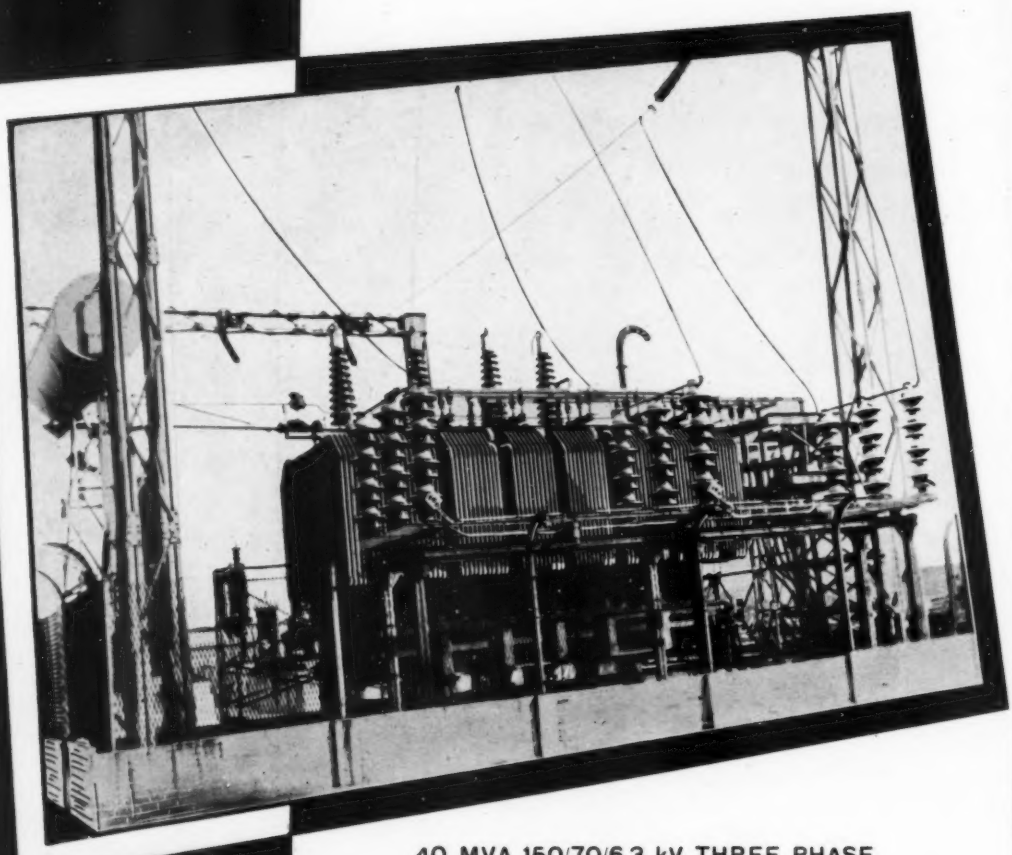
QUEENS HOUSE, KINGSWAY, LONDON, W.C.2.

Switchgear Department, Stafford

WORKS: STAFFORD · PRESTON · RUGBY · BRADFORD · LIVERPOOL

SH.A

All classes of electrical equipment for power stations and networks



40 MVA 150/70/6,3 kV THREE PHASE TRANSFORMER

Type RFR4 on load tap changing device on the HT side

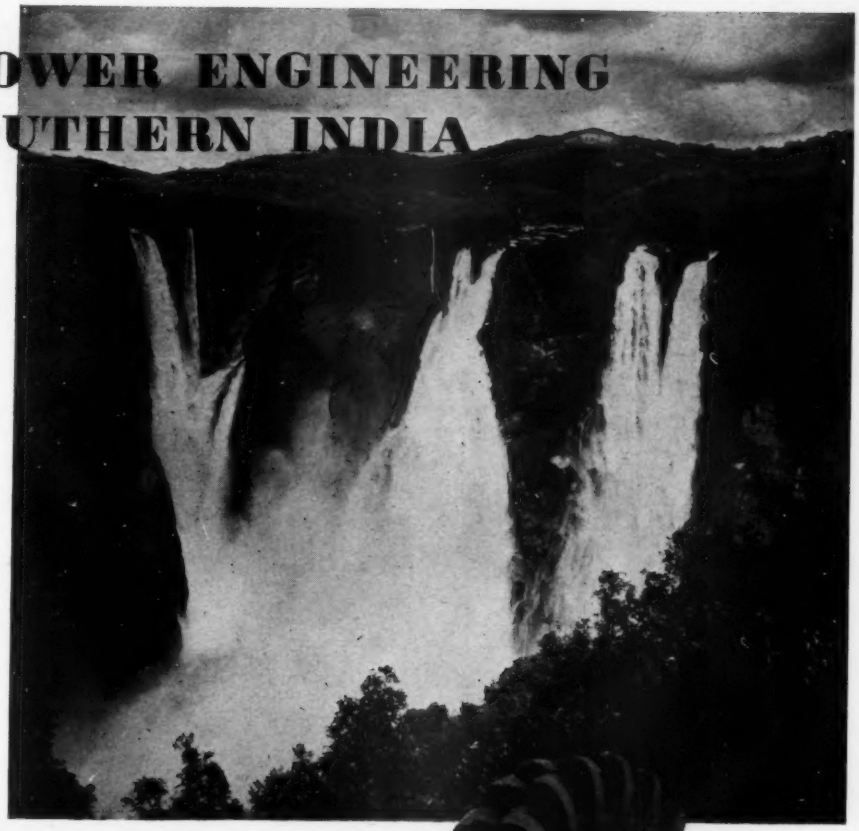
Installed at the Droogenbosch
Power Station of the
Union Intercommunale des Centrales Electriques
du Brabant

Ateliers de Constructions Electriques de Charleroi

Charleroi · Belgium

CHARLEROI

WATER POWER ENGINEERING *in* SOUTHERN INDIA



The first four 19,000 h.p. Pelton Turbines installed for the Government of Mysore at the Jog Falls Station came into commercial service at the end of 1948.
Further extensions to this Station comprise four double runner 4-jet horizontal shaft Peltons, each designed to develop 32,500 h.p. under a nett head of 1190 feet.

Manufactured at the Works of Markham & Co. Ltd., Chesterfield.

Boving
& COMPANY LIMITED

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Head Office:
56, KINGSWAY, LONDON, W.C.2, ENGLAND

Branch Offices: Wellington: Druids Chambers, Woodward Street.
Melbourne: 99 Queen Street.
Calcutta: c/o Messrs. Macneill & Barry Ltd., 2 Fairlie Place.
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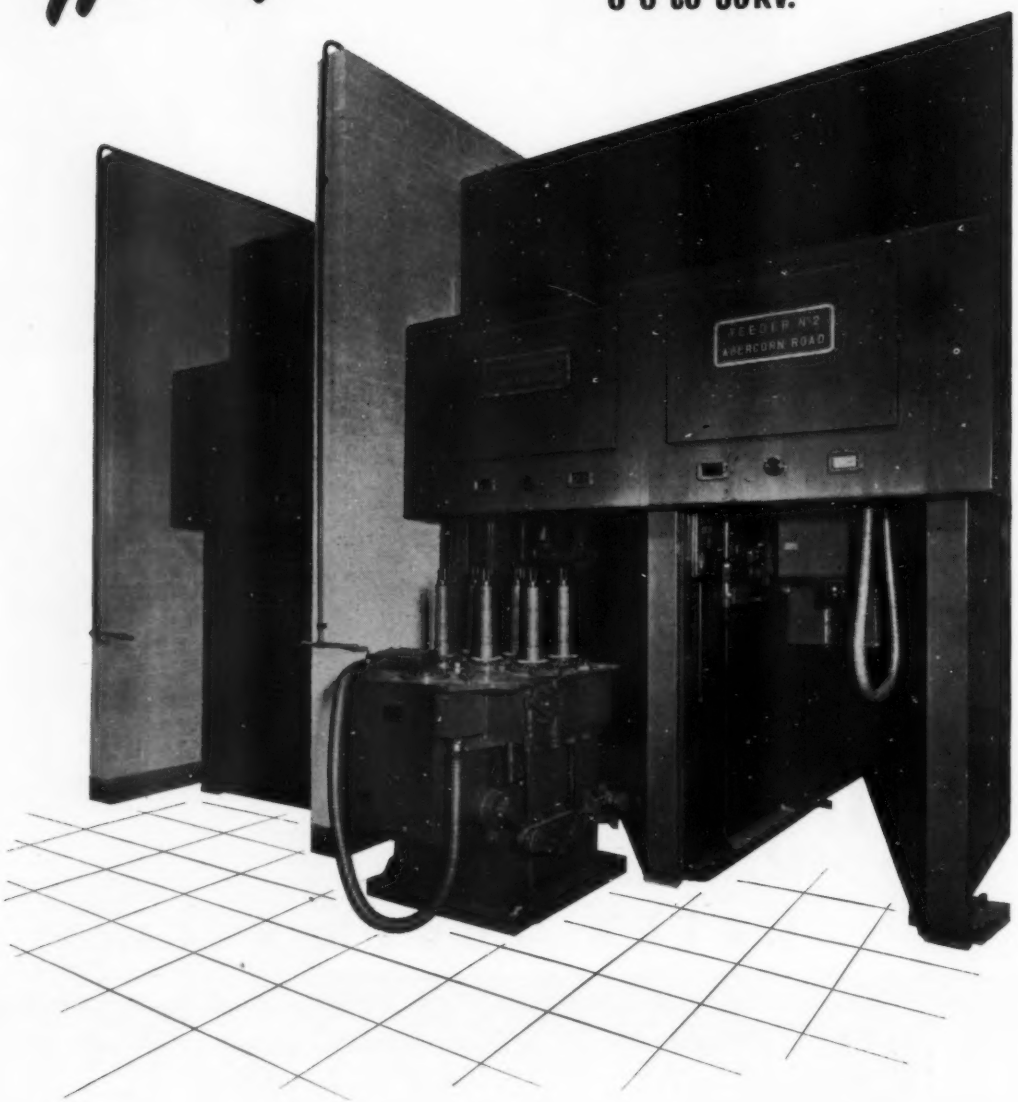
Representatives in all parts of the world.

B.C. 3

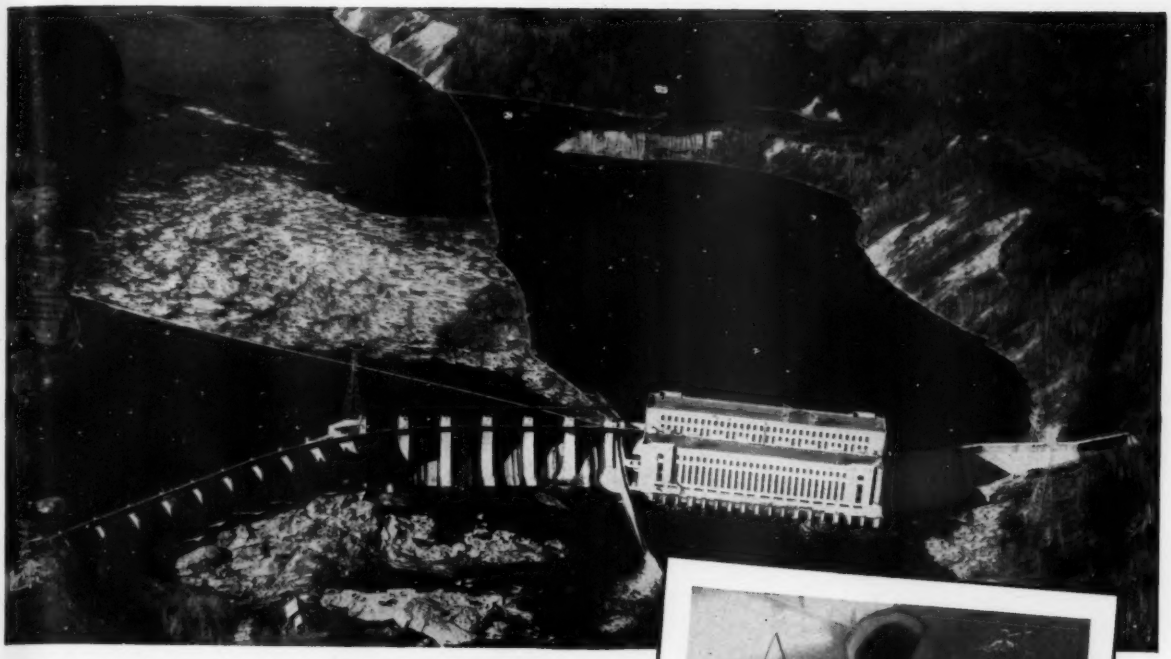
G.E.C. Low oil content

Heavy Duty Switchgear

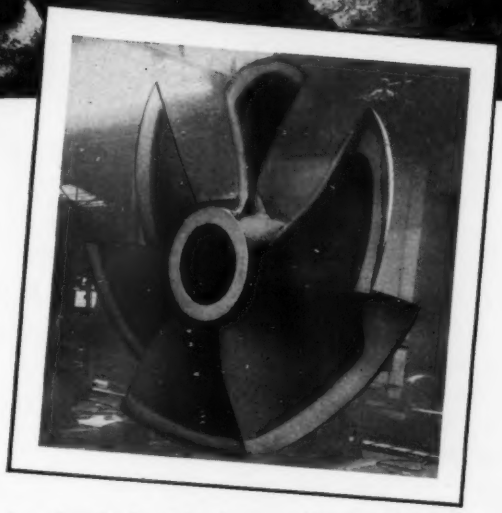
500 to 1500 MVA,
6·6 to 33kV.



THE GENERAL ELECTRIC CO. LTD., MAGNET HOUSE, KINGSWAY, LONDON, W.C.2



The La Gabelle plant of the Shawinigan Water and Power Company, containing five Dominion fixed blade propeller turbines of 35,000 H.P. each, at 120 R.P.M. under a head of 60 feet.



Economy with DOMINION PROPELLER TURBINES

For low head hydro-electric power plants, where high speed is essential for economy in capital cost, the fixed blade propeller turbine is often the most suitable particularly when there are multiple units in the power house.

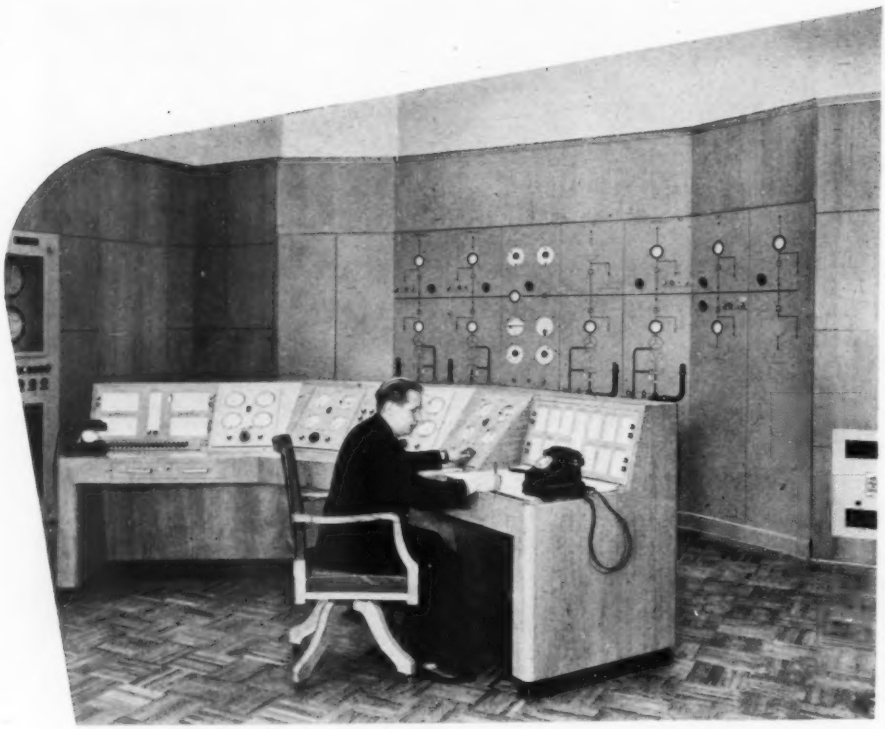
The fixed blade propeller turbine is as simple in construction and operation as the lower speed Francis turbine. It does not require the complicated mechanism and governor control, in the rotating element, of the adjustable blade propeller turbine. Nevertheless, the fixed blade propeller turbine, in many installations, utilizes the available hydraulic power as effectively as the more expensive type.

Since 1921 Dominion Engineering have received orders for 89 fixed blade propeller turbines with a total rated capacity of 1,244,245 H.P., and are now manufacturing 14 units of this type, with throat diameter of 205". Eight units, of 21,000 H.P. each, at 94.7 R.P.M. under a head of 40 ft. are for the Chenaux Development of Hydro-Electric Power Commission of Ontario, and six units of 19,000 H.P. each, at 94.7 R.P.M. under a head of 37 ft. are for the Pine Falls Development of Department of Mines & Natural Resources, Province of Manitoba.

This background of experience, combined with a systematic research programme in our own laboratory, is at your service. We confidently invite your enquiries.

4907

DOMINION ENGINEERING
COMPANY LIMITED
MONTREAL, CANADA **D** **CABLE: DOMWORKS**



128 MW at 132 kV under fingertip control

STANDARD Generator Control desk and mimic diagram at Loch Sloy power station provides full facilities for direct indication and control of four 32 MW generators and six 132 kV feeders. Generator controls include Raise-Lower speed, Raise-Lower excitation and Open-Close generator circuit breaker. Fingertip controls operate 50V D.C. circuits at a few milliamps, enabling telephone cable to be used instead of the multi-core V.I.R. cable needed with older systems. All protective devices are continuously monitored and indicated by a STANDARD Direct Wire Alarm system.

LEADERS for 30 years in the field of remote control of switchgear, *Standard* have installed systems throughout the world. Now, at Loch Sloy, *Standard* again lead with the first Miniature Direct Wire Remote control system to be applied to the control of hydro-electric generators.

At LOCH SLOY, the most modern hydro-electric power station in the world, all turbine, generator, switchgear controls and meters necessary for synchronising and efficient loading have been centralised in the control room by means of *Standard* Miniature Direct Wire Remote Control.

Using entirely telephone-type apparatus, this advanced control system convincingly demonstrates that miniature, easy-to-handle equipment is safe and reliable when applied to the control of the largest generators and is indicative of *Standard's* ability to meet, in the field of telecommunications, the most exacting requirements of modern power generation.

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AERIAL CABLEWAYS
for Hydro-Electric Schemes
Night and day in all weathers Henderson Aerial Cableways consistently maintain scheduled construction programmes. The speed, economy and efficiency of Henderson Cableways are essential factors in large building, constructional and hydro-electric undertakings. Henderson Cableways were used for the construction of the Dams at Loch Sloy and Glen Shira, North Scotland, Hydro-Electric Board, and various other home and overseas undertakings.

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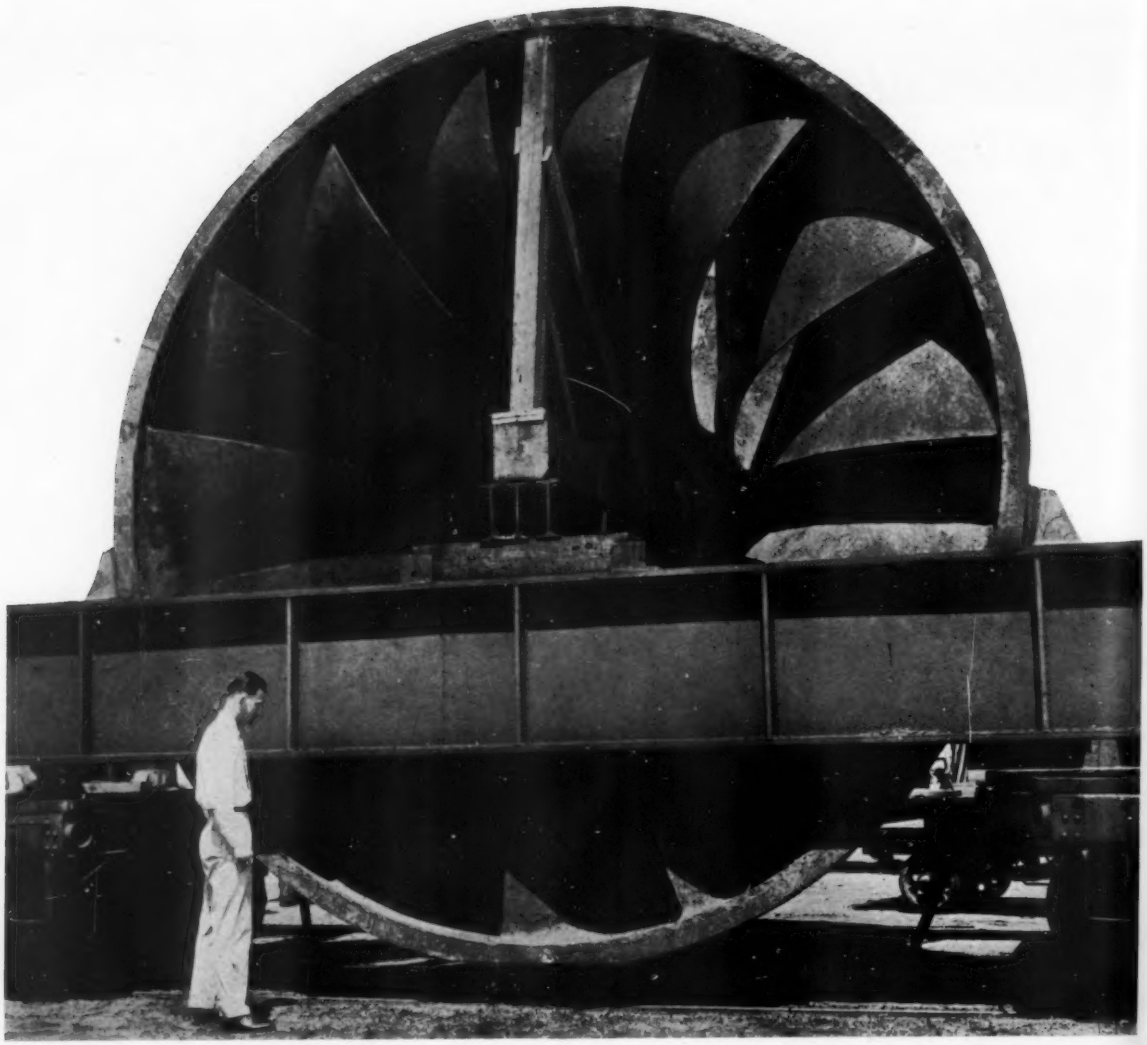

FACILITIES FOR THE SMALLEST OR LARGEST

The 225-acre Newport News plant includes plate steel and machine shops equipped with a complete variety of tools to fabricate items of water power equipment of any size. Contracts received by Newport News for hydraulic turbines with an aggregate rated output in excess of 7,000,000 horsepower have included units as high as 165,000 horsepower and as low as 500 horsepower.

Supplementing the extensive facilities are the equally important experienced and skilled personnel at Newport News to design and build such equipment.

Your inquiries for hydraulic turbines of any size will receive prompt attention.

Write for illustrated booklet on water power equipment.

NEWPORT NEWS

SHIPBUILDING AND DRY DOCK CO.

NEWPORT NEWS, VIRGINIA, U.S.A.

Here's a single-feeder substation delivered in *One Compact Unit*

Delivered in one shipment from one supplier, a Westinghouse "CSP"® Power Transformer is the quickest, easiest, most economical method of setting up a complete single-feeder substation. Eliminating expensive and time-consuming coordination of the 43 separate components required for conventional substations, Westinghouse "CSP" Transformers perform all the functions of a single-feeder substation—complete lightning, surge and fault protection; automatic voltage regulation, load switching and metering. They are neat, compact and easy to landscape.

Simple to order, easy to install and maintain, "CSP" Transformers can be moved quickly and inexpensively if load centers change. If loads grow, more units can easily be tied into the line.

BETTER, MORE ECONOMICAL OPERATION

In urban . . . suburban . . . industrial and rural areas—Westinghouse "CSP" Transformers assure better operation through 3-way protection: against lightning and impulse voltages, system short circuits and dangerous overloads. Metal enclosed construction also eliminates service interruption from various external causes. All equipment—even safety fuses—is inside the cabinet. Costs of maintaining "CSP" Units are less than for any other single-circuit substation—regardless of type.

For complete information about Westinghouse "CSP" Power Transformers write for your free copy of Booklet B-4692.

YOU CAN BE *SURE* . . . IF IT'S

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WESTINGHOUSE ELECTRIC INTERNATIONAL COMPANY

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GREATEST FOOTAGE—LEAST FATIGUE

The R.V.240—a rapid-striking drill specially designed for use with Tungsten Carbide bits**—does the drilling, the "Maxleg" does the supporting and the operator escapes fatigue; which is the economical way of using both men and machines. Holes can be drilled in any position (even right down on the ground) and in the hardest rock with the same ease. As to speed, the pneumatic feed of the "Maxleg" ensures not only more accurate but also much faster drilling than is possible by hand.**

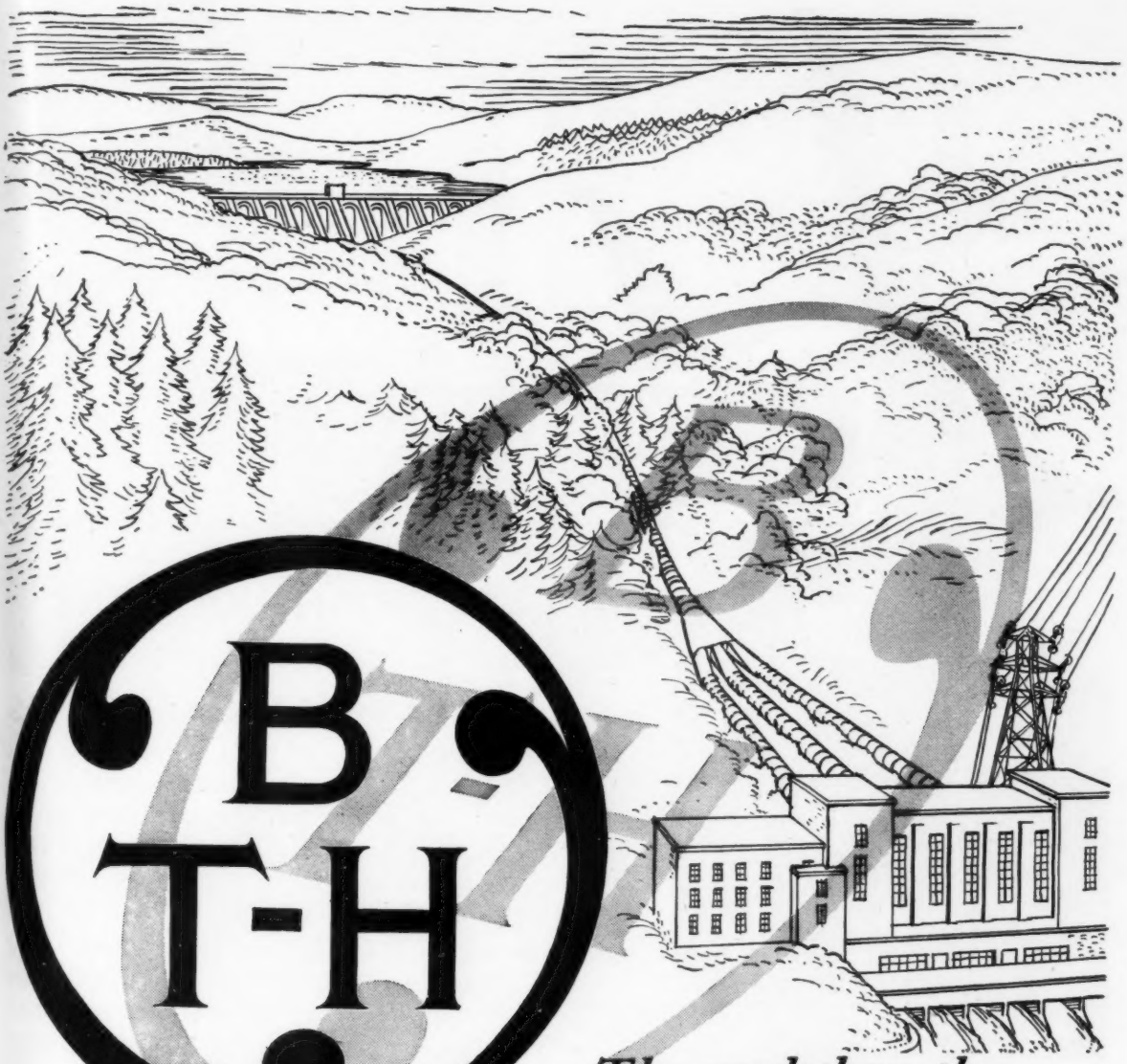
The R.V.240-MAXBIT combination used with the "Maxleg", ensures increased efficiency all round.

CLIMAX

CLIMAX ROCK DRILL & ENGINEERING WORKS LTD.

4, Broad Street Place, London, E.C.2.

Works: Carn Brea, Cornwall.



B-T-H

The symbol on the
Best Electrical Equipment

Hydro-electric schemes call for heavy electric plant of exceptional reliability. That is why water-power engineers turn naturally to BTH, one of the world's greatest electrical firms and noted for the quality of its products. But this is only one direction in which BTH are specialists. They enjoy the same high reputation in marine circles, in mining, general engineering, and the aircraft industry. With over fifty-four years' experience and eleven factories, BTH is able to give outstanding service in every sphere of electrical engineering.

THE
BRITISH THOMSON-HOUSTON
COMPANY LIMITED, RUGBY, ENGLAND

Member of the AEI group of companies

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for

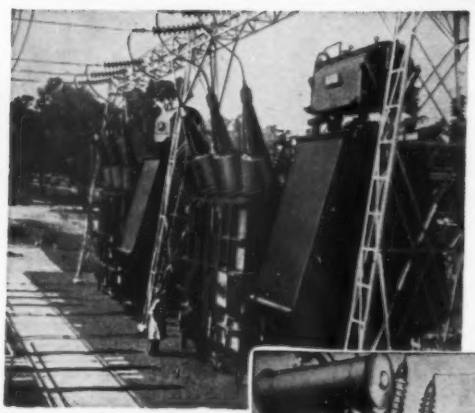
HIGH VOLTAGES

and in the

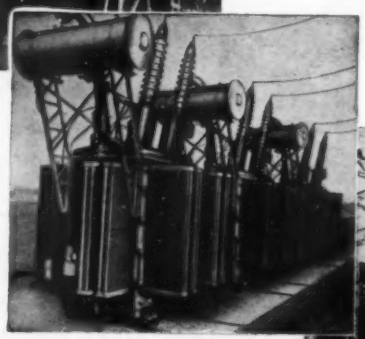
LARGEST CAPACITIES

HACKBRIDGE Transformers include some of the world's largest units — in capacities up to 94,000 kVA. three-phase and for voltages up to 170 kV. —many of these being in service in hydro-electric power stations.

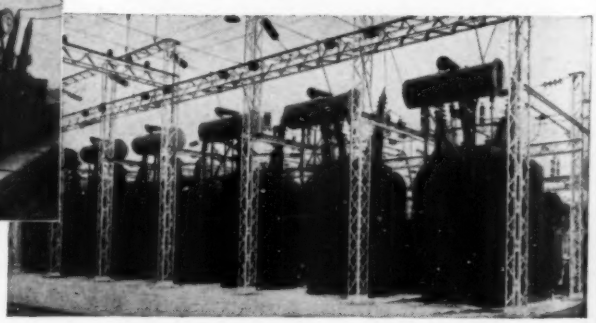
Through over a quarter of a century, these — and all other types of Hackbridge transformers —have achieved a magnificent reputation for reliability and sound modern design and construction.



An installation of large Hackbridge transformers in Australia.



Three 6,666 kVA single-phase Hackbridge transformers forming 20,000 kVA 110/38.5/6.6 kV. 3-phase bank.

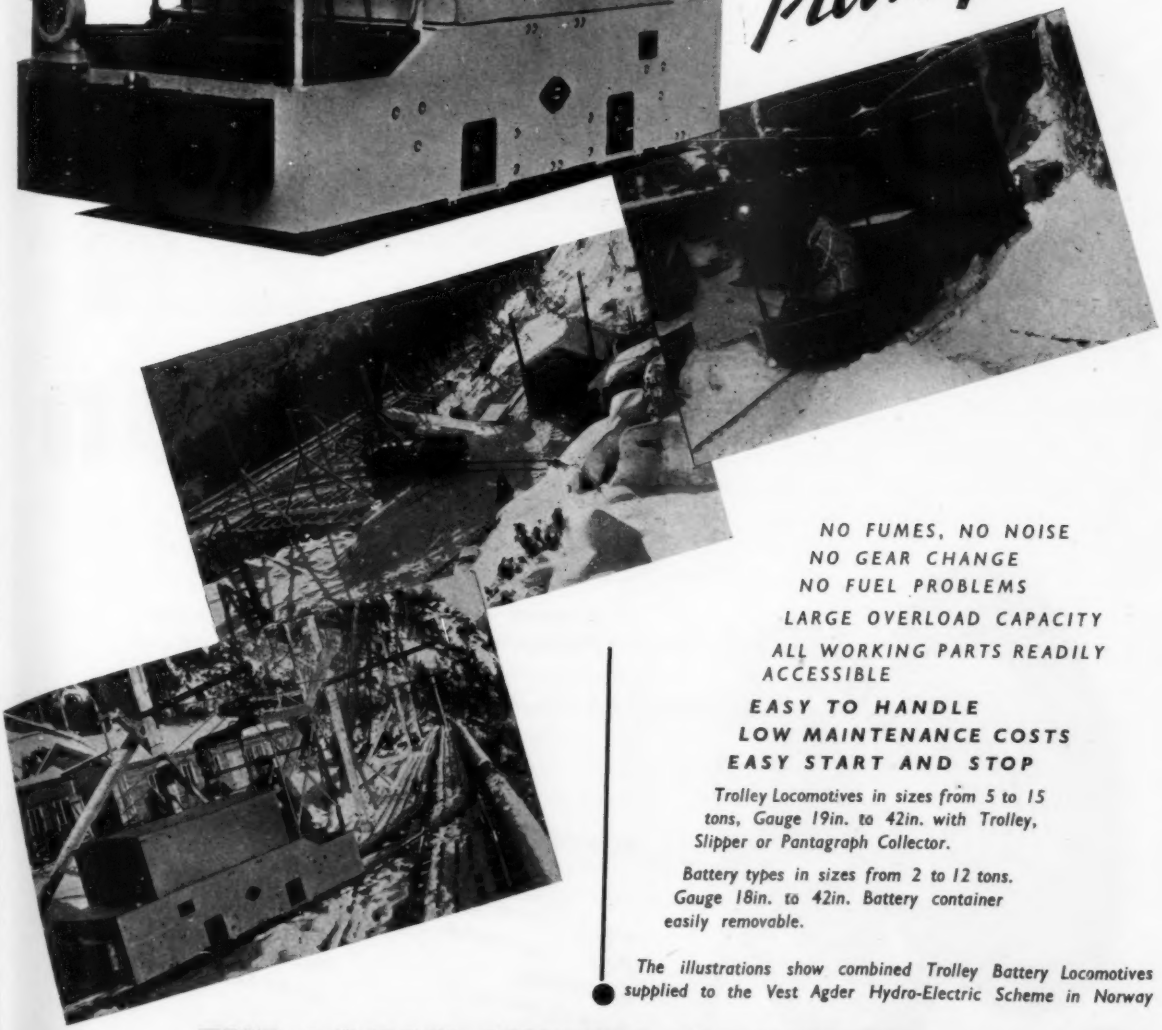


Two 18,500 kVA. 3-phase 102/11/6.6 kV. banks of Hackbridge transformers installed in Tasmania.

HACKBRIDGE AND HEWITTIC ELECTRIC CO. LTD., WALTON-ON-THAMES, SURREY

Telephone: Walton-on-Thames 760 (8 lines) Telegrams: "Electric," Walton-on-Thames

LOGAN for Tunnelling Transport



NO FUMES, NO NOISE
NO GEAR CHANGE
NO FUEL PROBLEMS
LARGE OVERLOAD CAPACITY
ALL WORKING PARTS READILY ACCESSIBLE

EASY TO HANDLE
LOW MAINTENANCE COSTS
EASY START AND STOP

Trolley Locomotives in sizes from 5 to 15 tons, Gauge 19in. to 42in. with Trolley, Slipper or Pantagraph Collector.

Battery types in sizes from 2 to 12 tons. Gauge 18in. to 42in. Battery container easily removable.

The illustrations show combined Trolley Battery Locomotives supplied to the Vest Agder Hydro-Electric Scheme in Norway

THE LOGAN MINING MACHINERY CO. LTD.

GRAY STREET WORKS
LOCHEE · DUNDEE

Telephone: 68264-5 *Telegrams: "WALCO"*

Save Wiring Time this way

It always pays to buy the best rubber cable that is made—Crompton cable. You save in wiremen's time because this cable is easy to strip and easy to draw through conduit. Inch by inch, mile after mile, there is no variation in the high quality of conductor and insulating materials. For your next wiring job, specify Crompton cables; they are made in accordance with the standards and formulae of the C.M.A. of which we are members. Special consideration is given to the requirements of Overseas Specifications.

Crompton

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CROMPTON PARKINSON LTD. (OVERSEAS DIVISION), CROMPTON HOUSE, ALDWYCH, LONDON, W.C.2, ENGLAND

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D.C. GENERATORS
BATTERIES · INSTRUMENTS
TRACTION EQUIPMENT
CEILING FANS

Shop Window For British Engineering

Tummel-Garry Scheme, Pitlochry Dam

The North of Scotland Hydro-Electric Board are harnessing the water power resources of the Highlands of Scotland, which are estimated to have a potential annual output of 10,000,000,000 kilowatt hours, distributing electricity in an area of 21,750 square miles and also supplying power to Britain's National Grid.

More than one hundred hydro-electric schemes are visualised in this development.

Schemes with an estimated annual output of 3,300,000,000 kilowatt hours and a kilowatt capacity of 1,126,000 are in operation, under construction or in preparation.

On the doorstep of world-famous engineering firms the visitor will see a wide range of generating machinery and equipment operating under diverse conditions.

NORTH OF SCOTLAND HYDRO-ELECTRIC BOARD

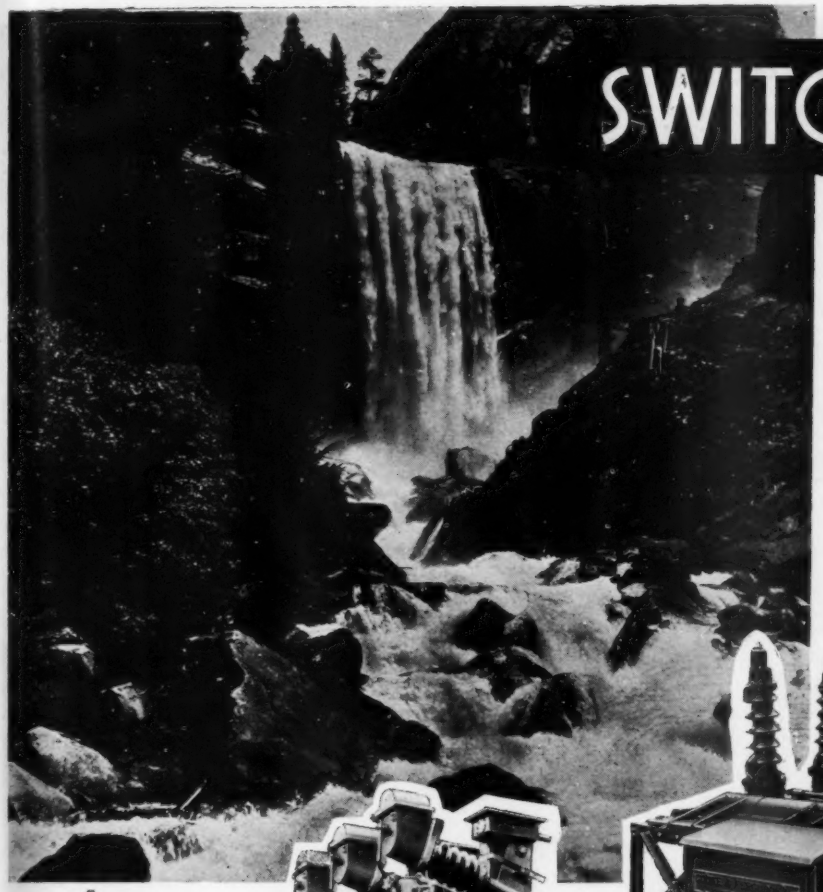
The SHORTEST distance between two points ....

Made in Great Britain

CERETTI & TANFANI ROPEWAY CO. LTD.

Imperial House, Dominion Street, London, E.C.2.

CLErkenwell 1777 (8 lines)

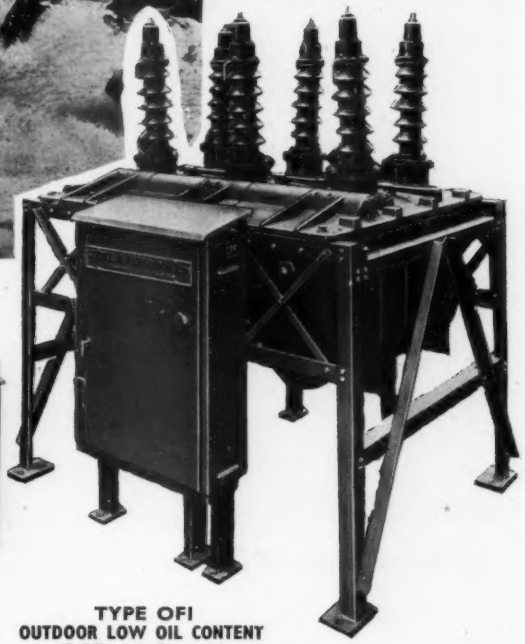


SWITCHGEAR

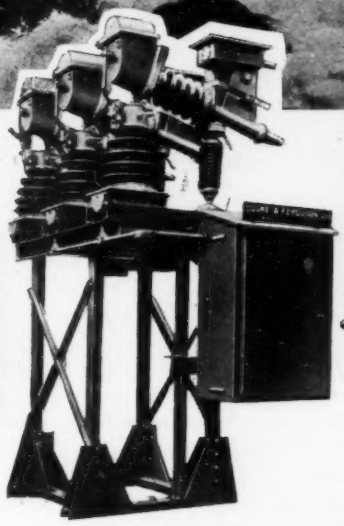
for

HYDRO ELECTRIC SCHEMES

Three examples from the C and F range of Outdoor Oil Circuit Breakers are illustrated below. The complete range extends from 2,000 volts to 138 kV for both indoor and outdoor service under the most arduous conditions.



TYPE OF1
OUTDOOR LOW OIL CONTENT
O.C.B. rated up to
2,500 M.V.A. 69 kV (A.S.A.)
1,500 M.V.A. 66 kV (B.S.)



TYPE OE6
OUTDOOR LOW OIL CONTENT
O.C.B. rated up to
1,500 M.V.A. 46kV (A.S.A.)
1,500 M.V.A. 44kV (B.S.)

TYPE OE5
OUTDOOR LOW OIL CONTENT
O.C.B. rated up to
1,500 M.V.A. 34.5 kV (A.S.A.)
1,000 M.V.A. 33kV (B.S.)

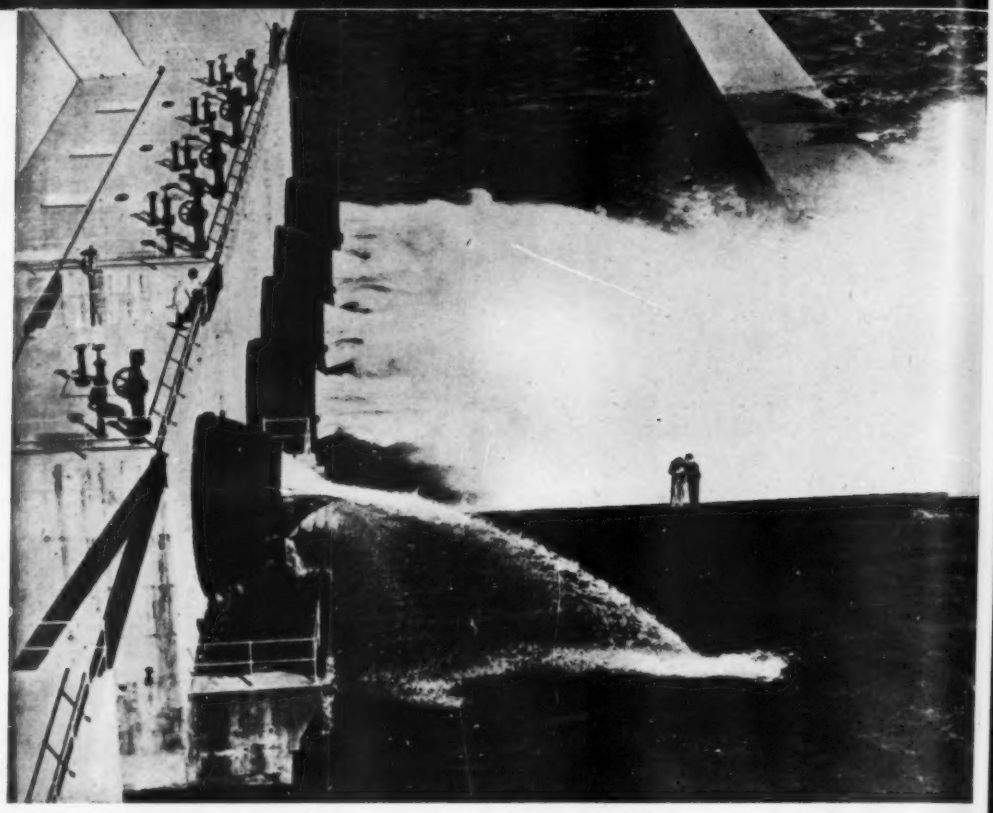
FULL PARTICULARS SENT ON APPLICATION

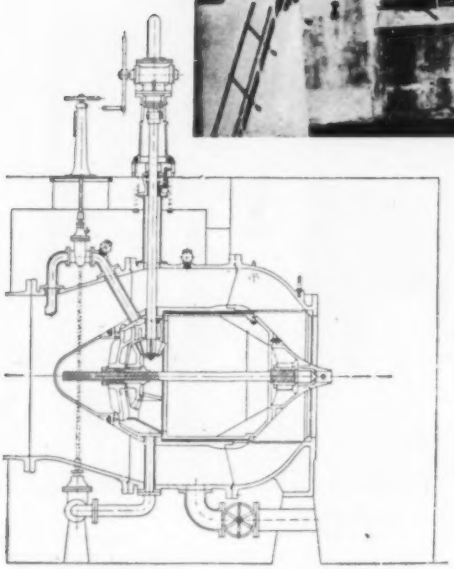
COOKE & FERGUSON Ltd.

Switchgear Specialists

VICTORIA STREET OPENSHAW MANCHESTER 11

DISCHARGE REGULATORS FOR DAM OUTLETS



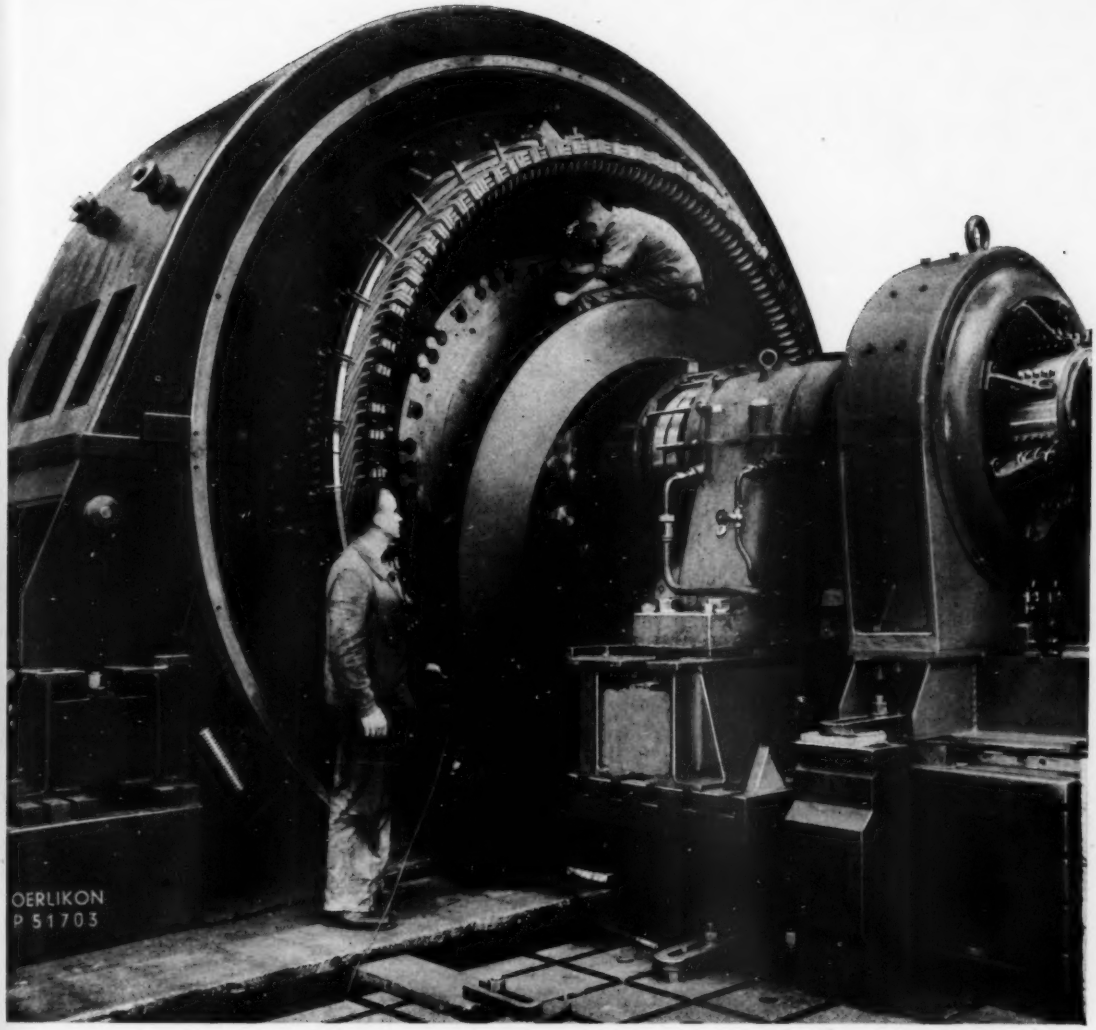


The Larner-Johnson valve possesses exceptional qualities for free discharge control. No other valve provides so complete an answer to the dual problems of high velocity flow and hydraulic unbalance associated with this duty. Being of true streamline form, it passes a smooth jet at all openings, giving freedom from vibration and erosion under the highest heads. Operation is by means of the pipe line pressure acting on the plunger, governed by an internal pilot valve control which holds the plunger in balance at all open positions (when stationary) and creates the appropriate unbalance for opening or closing. Ease of operation is thus ensured, irrespective of size or pressure. Simplicity of design, freedom from distortion troubles, absence of sliding surfaces under pressure, all contribute to the success of the valve over the full range of conditions. Some of the largest valves of their class are of Larner-Johnson type, amongst them the three 13 ft. by 7 ft. 6 in. and four 9 ft. by 7 ft. 6 in. regulators at Hume Dam, on the Murray River, Australia, certain of which appear in the adjoining photographic view.

Full particulars from : **J. Blakeborough & Sons Ltd.**, Brighouse, England.

BLAKEBOROUGH

75 Years OERLIKON 1876—1951



Assembly at the Oerlikon works of a horizontal generator of 40,000 kVA. Two units of this output were supplied to a Power station in Norway.

Some large generators under construction at the Oerlikon works:

2	vertical units, each of	49,500 kVA	for Egypt.
1	„ unit of	50,000 kVA	„ Mexico.
2	„ units, each of	10,000 kVA	„ „
2	horizontal units each of	63,000 kVA	„ France,
5	horiz. units, total output	175,000 kVA	„ Switzerland.
2	vertical units, total output	105,000 kVA	„ „

OERLIKON ENGINEERING COMPANY, ZURICH 50 (SWITZERLAND)

Agencies and Representatives:

Great Britain: Oerlikon Ltd., Victoria House, Southampton Row, London, W.C.1.—**United States:** Pacific Oerlikon Company, Box 1133, Tacoma 1, Washington.—**Canada:** Oerlikon-Canada Limited, 1514 University Tower Building, Montreal.—**India:** Larsen & Toubro Limited, P.O.B. 278, Bombay 1.—**South Africa:** A. M. Burgun, Mech. Engineer, 604, Maritime House, Loveday Street, Johannesburg.

Arrol

Poulaphouca, with this Hydro-Electric Station, takes its place on the map as a landmark of progressive Eire. The surge tank, penstocks and 100 ton power station crane are part of an Arrol contract which also called for the provision of a 70 ton inclined platform hoist shown on the left of the illustration.

SIR WILLIAM ARROL & CO. LTD., GLASGOW.

All types of Steel Framed Buildings, Fixed and Opening Bridges, Cranes and Mechanical Engineering work, Dock Gates, Sliding and Floating Caissons, Compressed Air Locks, Hydraulic Machinery, Pipe Lines, Surge Tanks, Sluices and other equipment for Hydro-Electric Stations.

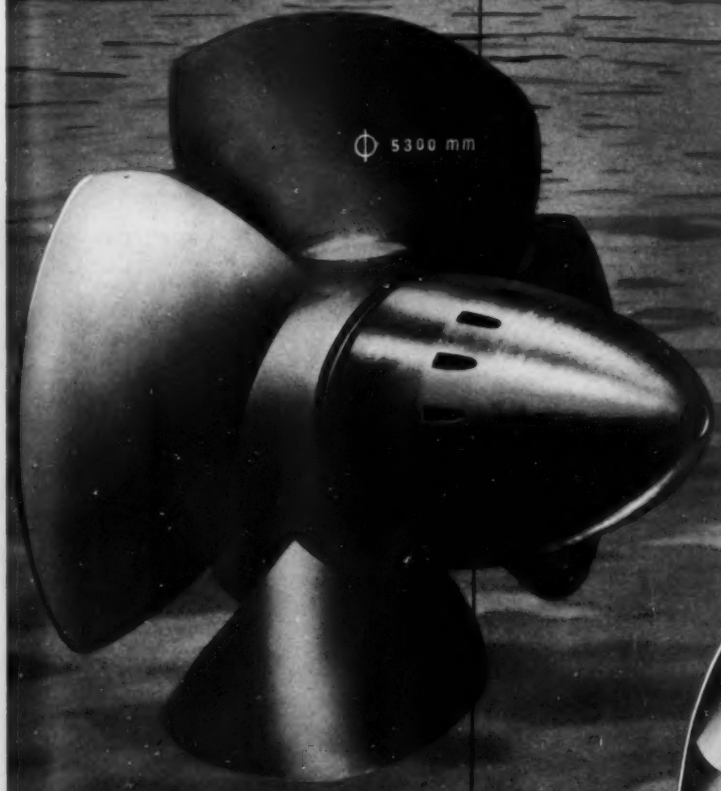
Hydro-Electric Station, Poulaphouca, Eire. Surge Tank, Pen-Stocks, 70 ton inclined Platform Hoist and 100 ton Power Station Crcne manufactured and installed by Sir William Arrol & Company Limited.

Hopwood

WATER TURBINES

KAPLAN

PELTON



Pipelines
Sluice Gates
Travelling Cranes

FRANCIS

KRIENS Bell

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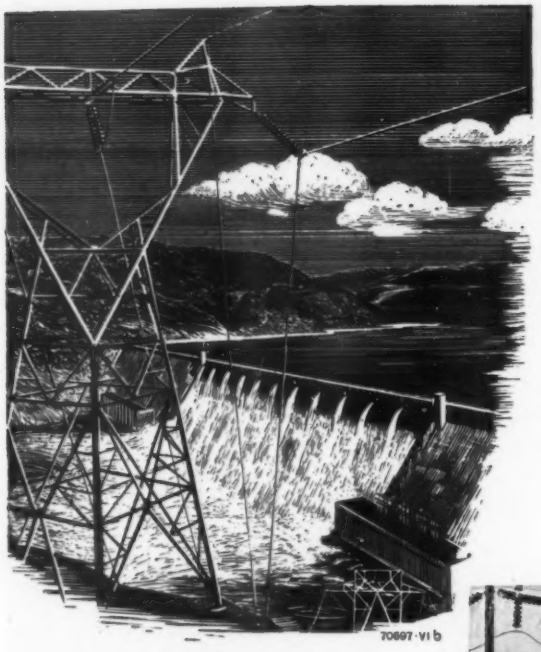

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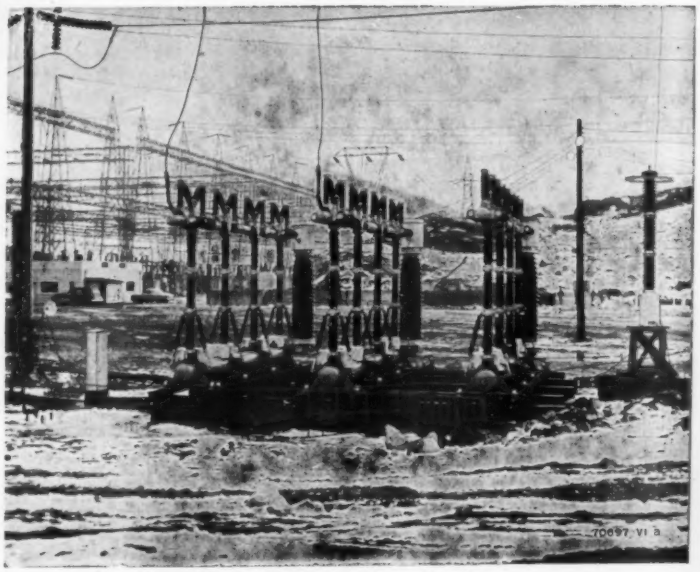

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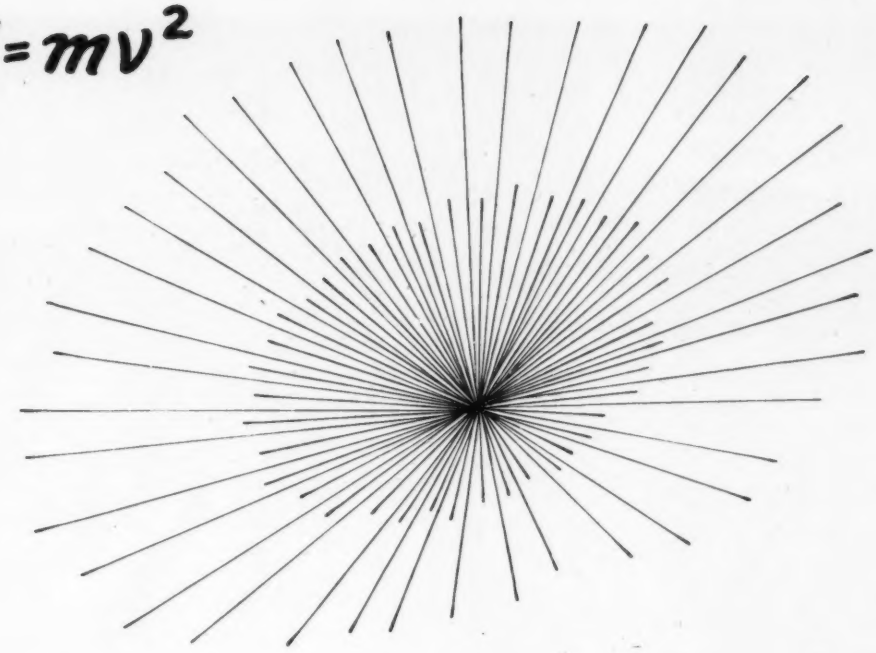

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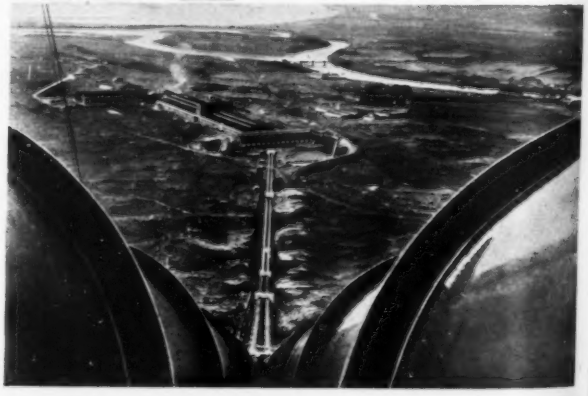
THE two illustrations show views of a section of the Lochaber Power Scheme, which involved the construction of three large Dams, about twenty miles of concrete lined Tunnels, five Pipelines each 3,200 feet long, a Power House, Factory foundations, Tail Race and ancillary works.



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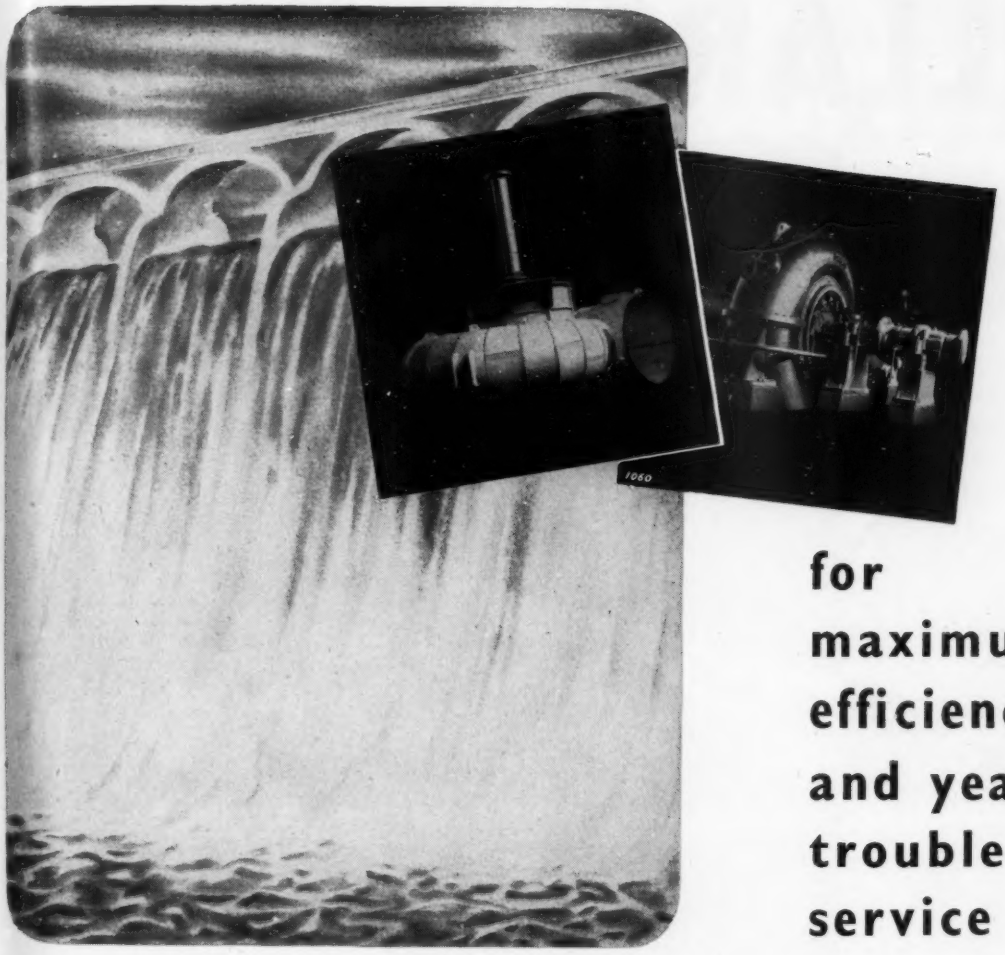

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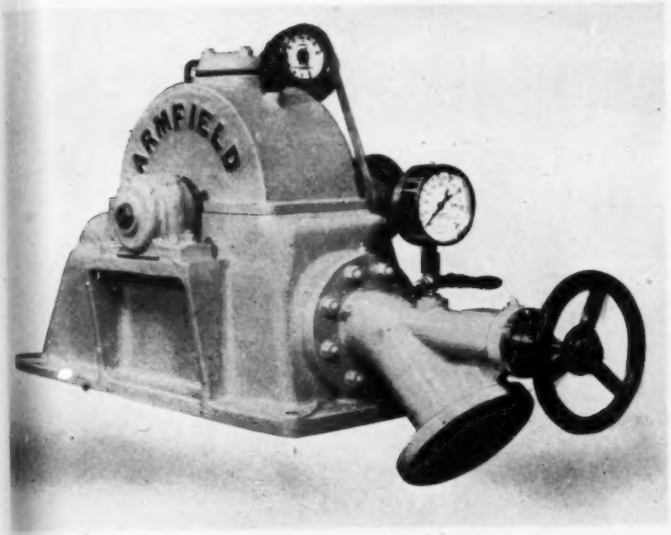

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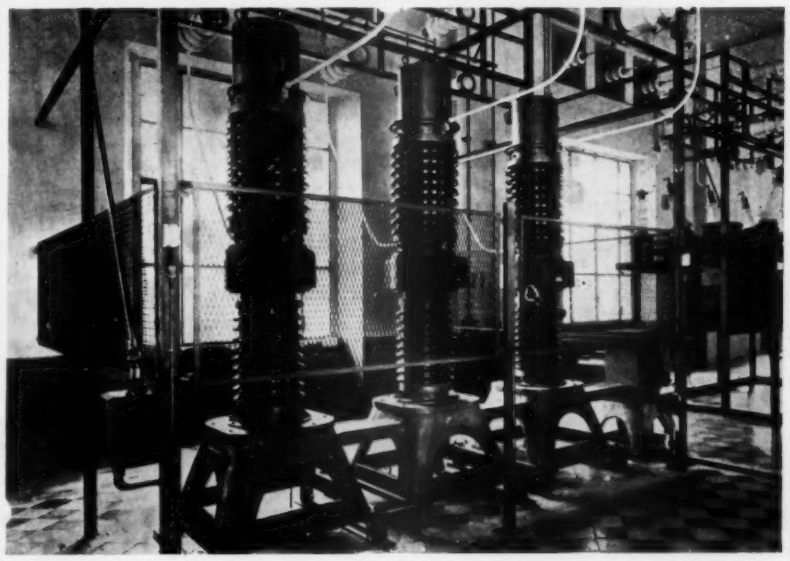

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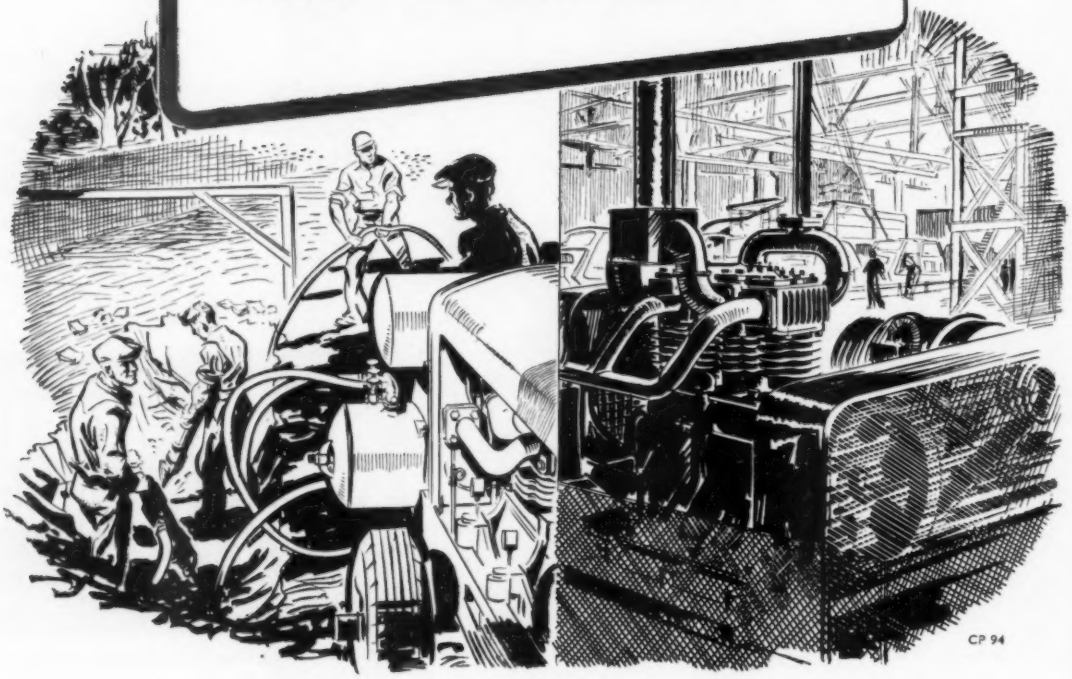

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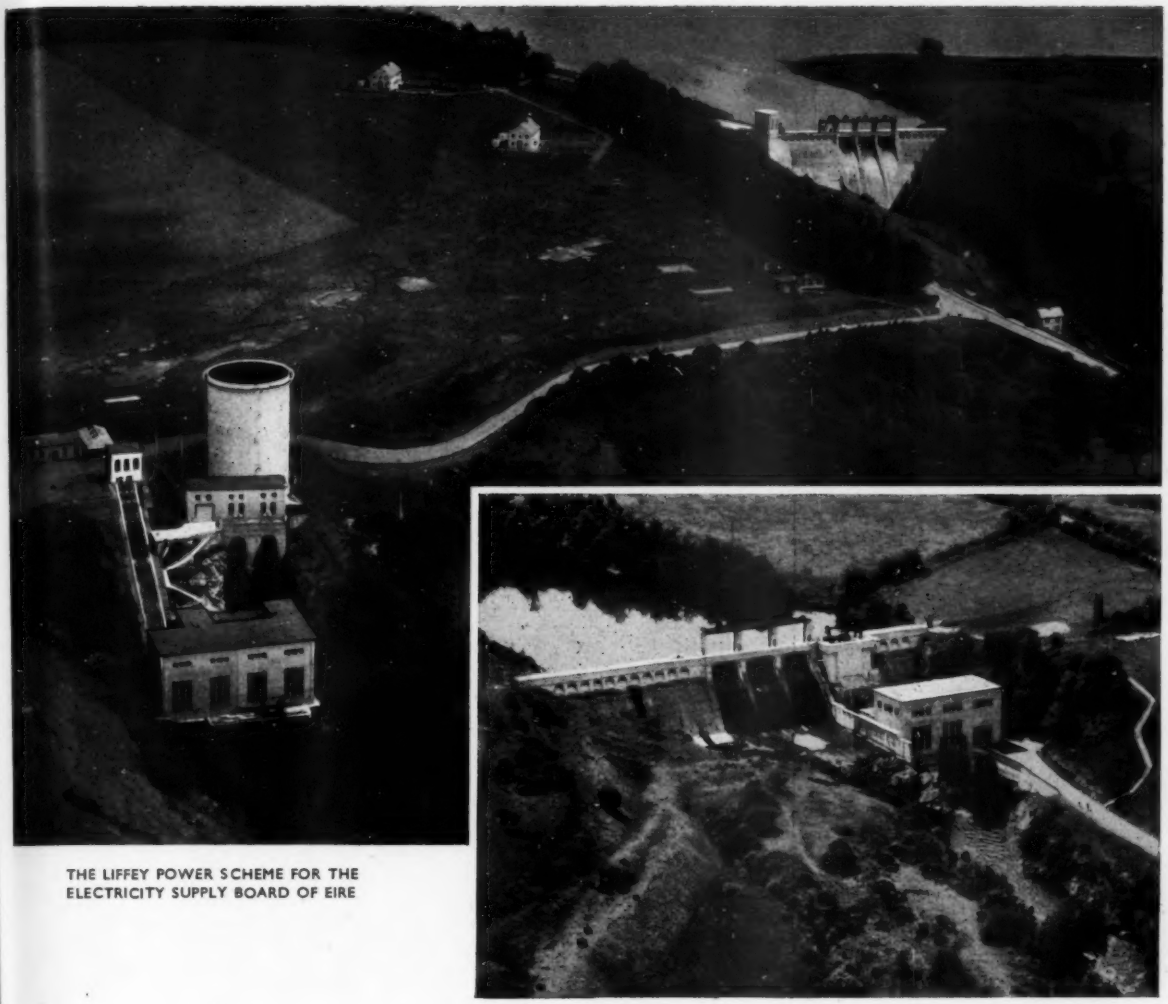

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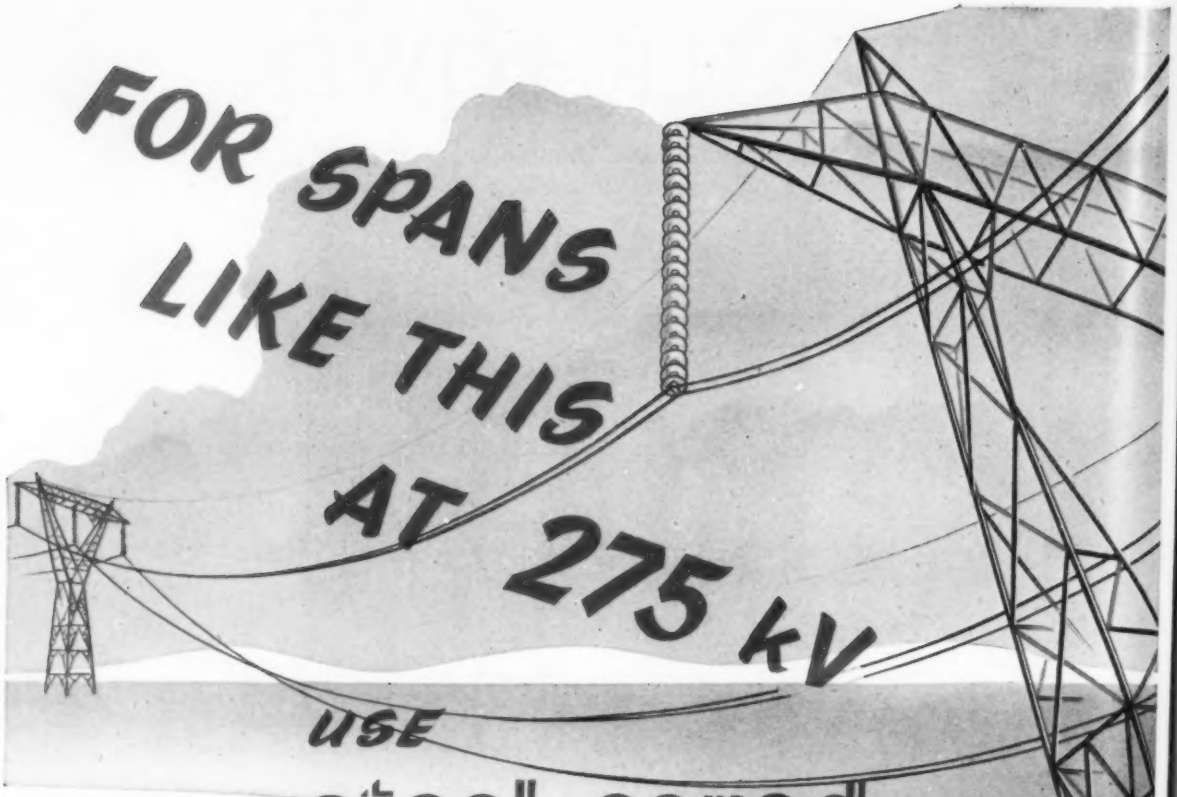

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S.E. Asia—Opportunity and Warning

LAST month we discussed the task of repowering Europe. We have now to consider the even wider, but not less important field of the Far East, to which the eyes of the world have been anxiously turned during the last twelve months, and rather more hopefully in the last few weeks. The slight easing of the international tension brought about by the armistice talks on Korea, however, affords no occasion for any slackening of effort by the western powers. What it does call for is a change of direction — in fact a redirection — of development plans. It demands a new and intense concentration on developments that will produce dividends in the form of improved conditions for the increasing millions of South-East Asia in place of the almost wholly uneconomic expenditure associated with war armaments.

What may fairly be termed the free world's armed preparedness is too frequently regarded as a full armaments programme. In fact it is nothing like that. A fairly reliable estimate has put the present defensive efforts of the western powers generally at not more than 25 per cent. of an all-out armaments drive. In this respect Mr. Paul Hoffman, the former head of the U.S. Economic Co-operation Administration, put the situation concisely but clearly in Lisbon recently when he observed: "If the free world will use its resources it can make such progress in this decade of the fifties that no force will ever dare to attack it."

The Colombo Plan for South-East Asia presents a notable opportunity for the wise employment of these resources. But to-day, at the outset of its practical application and implementation, it discloses a disconcertingly contrasted, two-sided picture. The progress of the technical bureau associated with the plan was seen last month at the second policy meeting of the Council for Technical Co-operation. The appointment of Mr. Geoffrey Wilson, assistant secretary of the United Kingdom central planning staff as director of the bureau is an indication that this progress will be continued, and, given favourable conditions, accelerated. It is to be hoped, indeed, that all non-Commonwealth countries in the vast area covered by the plan will become full members of the bureau.

Against this hopeful technical advancement has to be placed the equally important, but at present less satisfactory financial side of the picture. Doubts have been expressed in some quarters as to whether the full financial support needed will be realised. Yet there is no part of the world in which the need for effecting economic improvement is more urgent. Everywhere in the area populations are increasing, and if rates of increase are maintained the present population of some 570 million will have grown to something like 720 million before another score of years have passed; an increase, be it noted, approximating to the total population of the United States to-day. Increased production, both agricultural and industrial, is essential to provide for this substantial growth in population. As the plan itself very properly emphasises, "the problem is one of increasing the capital equipment of the countries not only to keep pace with the growing population but also, through increased production per head, to permit some rise in the level of consumption."

Power resources there are in plenty in this economically poor—because undeveloped—area of the world. Experts who have worked long in investigating the situation declare categorically that "the hydro-electric power resources of the area have hardly yet been tapped," and in nearly all the countries the application of capital would enable large tracts of land to be brought under cultivation. The fuel and power development programmes of the British Commonwealth countries within the plan — India, Pakistan, Ceylon, Malay and British Borneo—represent together an expenditure of roughly £122 million, or six per cent. of the total estimated expenditure on the entire South-East Asia Commonwealth programme of £1,868 million. In fact, electric power is one of the three basic developments vitally necessary to raise production of food and the raw materials for agriculture, and, like the other two, agriculture and transport, calls for acceleration and broadening of work in many instances already in progress.

What tangible results will flow from such Commonwealth developments? In terms of electrical power it

will mean an increase of between 60 and 70 per cent. in generating capacity (1,100,000 kW), 13 million more acres under cultivation, 6 million tons more of food grains, and 13 million acres more under irrigation (a 17 per cent. increase). Such an access of productive energy also would strengthen the financial position of the countries, both internal and external.

Admittedly this of itself would not raise the standards of living. Inevitably that must be a long-term effect. What the programme will do is to lay the foundations upon which can be superimposed the real Plan for Progress, leading to a more settled and satisfied, and therefore less vulnerable, South-East Asia, and a lessening, perhaps even a cessation, of world tension with its constant threat of world war. In pursuit of this aim the multi-purpose power and water projects alone can realise the all-important expansion of agriculture. Hence the great demand throughout the area for electrical, civil, mechanical and hydraulic engineers.

But the shortage of capital is still a main obstacle, and such capital must come largely from foreign investment. In the six-year planning period which opened last month the amount of external finance required by Commonwealth countries in the area has been put at nearly £1,100 million. It is a massive total, yet perhaps not too massive if international financial organisations remember the Commonwealth Consultative Committee's warning that " in an age when other countries are increasingly reaping the advantages of scientific and industrial advance, the hastening of a similar process in Asia cannot safely be delayed."

Colombo Plan Warning

UNEASINESS about the progress of the Colombo plan, especially in the fields of finance and supplies, is expressed by Mr. V. K. Rao, director of the Delhi School of Economics, giving an Indian view of the plan in the July number of Lloyds Bank Review. After stressing the importance of United States' co-operation in the six-year plan outlined, he urges the Commonwealth Governments who are participating to set up a joint agency to deal with financial co-operation, as they have already done for technical co-operation, incidentally the one field in which something like practical progress has been achieved. Mr. Rao warns that unless this machinery of financial and supplies co-operation is completed and functions actively there is little chance for the plan, as such, to succeed "and the grand conception of a multi-lingual and multi-racial Commonwealth working in co-operation to raise living standards within the less developed parts of its area would really have been in vain."

Europe's Raw Materials Shortage

DEVELOPMENT of the electricity position in Europe during recent months is one of many aspects examined in the second report by the Economic Committee of the Organisation for European Economic Co-operation. The exceptionally favourable conditions experienced during the past winter, it records, have enabled the production of electrical energy from hydraulic sources to reach a high level, while the shortage of coal has adversely affected the output of electricity from thermic sources in countries where this is the main source of power. Additional production capacity is urged in the supply of electric power as a principal means to a general increase in the production of various raw materials now in short supply. "International co-operation," it is urged, "must enable every member country to avoid exhausting itself in a multitude of less productive efforts, and to concentrate resources so as to increase the output of commodities which it is best fitted to produce."

Rhodesia Looking Ahead

THE far reaching effects of the Kariba Gorge hydro-electric scheme for Southern Rhodesia are the subject of significant comment in the latest progress report of the Prime Minister, Sir Godfrey Huggins. in regard to railway development. Big decisions will soon confront Southern Rhodesia, but the Prime Minister has assured the United Party Executive that each will be fully investigated, as the Government insists on a sound economic basis for the country's development. The Inter-Territorial Hydro-Electric Commission a few weeks ago received the report of the consulting engineeers on the Kariba Gorge scheme, and after examination the Commission has recommended its adoption in general and commencement of work as soon as possible.

£43½ m. Initial Scheme

THE Commission recommends the establishment of a Rhodesian Hydro-Electric Authority to finance, control and administer all installations at Kariba, together with the main transmission lines and associated equipment. The initial installation at Kariba would be of 385 MW for transmission at 220 kV to the two principal consuming centres — the copper fields of Northern Rhodesia and the Salisbury Midlands area of Southern Rhodesia. Estimated cost of the initial installation is £43.519 m., of which £23.424 m. is for heavy and light civil engineering works and £20.095 m. for the generating station, plant and transmission lines. Several years will be required for construction of works, and the Commission estimates that a minimum of eight years will be needed from receiving authority to proceed to the availability of power at consuming centres. The advisory panel of consulting engineers, on whose recommendations the Commission's report is based, consisted of Sir William Halcrow, M.I.C.E., M.I.Mech.E., partner of Messrs. Sir William Halcrow and Partners, London (chairman) and Mr. H. J. F. Gourley, M.Eng., M.I.C.E., partner of Messrs. Binnie, Dean and Gourley, London (civil engineers), and Mr. C. H. Pickworth, M.I.C.E., M.I.E.E., partner of Messrs. Preece, Cardew and Rider, London, and Mr. G. E. Kennedy, M.A., M.I.Mech.E., M.I.E.E., partner of Messrs. Kennedy & Donkin, London (electrical engineers).

Venezuelan Progress

THE Electricity Department of the Venezuelan Development Corporation is collaborating with the Irrigation Department in a multi-purpose hydro-electric scheme on the River Cojedes in Estado Portuguesa. A large dam is to be constructed to the north of San Rafael de Onoto, and will be fed by the Rivers Turbio, Nirgua and Cojedes. The dam wall will be approximately 654 feet in length, and it is

designed to irrigate an area of 123,500 acres. The available head will be of the order of 164 feet, and the initial hydro-electric development proposed envisages two generating sets each of 4,125 kVA. The power generated will be taken to a 33 kV transmission line to the towns of Araure and Acarigua, where there are a number of saw-mills. It is estimated that the plant will be in operation in about 1955.

Sir Edward McColl

BY the death of Sir (Albert) Edward McColl, the North of Scotland Hydro-Electric Board, of which he was Deputy Chairman and Chief Executive Officer, has suffered a very severe loss. Sir Edward McColl was more than a brilliant electrical engineer, he was a great and practical patriot who put his talent to work in the service of his native land; and the Board's great projects will be seen as monuments to him all over the Highlands.

A Scotsman by blood and by instincts, he saw in the harnessing of water power a source of regeneration for the nation he loved. The idea of using this source of energy had absorbed him as a young man and long before the Hydro-Electric Board had sprung into being he had surveyed the catchment area of what is now the Sloy scheme.

Sir Edward, who was 68 years of age at the time of his death, had a romantic career. Although recognised as one of the outstanding engineers in Britain, he was content to spend his working life in Scotland, where he served a youthful apprenticeship in John Brown's yard. In more recent years he was a very keen supporter of the Edinburgh Festival, and the performances of the Glyndebourne Opera Company gave him great delight; he was a clan historian and had a life-long interest in folklore.

Sir Edward endeared himself to his colleagues and he certainly took just pride in the thought that he was helping to bring light and warmth to a part of the world that had found these comforts difficult to obtain; he saw the Board as an agency which might galvanise the whole life of the Highlands and send inspiring vital currents through the people whose interests had been neglected. The restoration or the introduction of intelligent craftsmanship were also objects dear to his heart.

Because of Sir Edward McColl's death the opening ceremony at Clunie power station near Pitlochry, which was to have been performed by Lady McColl in June, was cancelled—the ceremony was to have marked the completion of the first stage of the Tummel-Garry scheme.

Needs of Turkey

RECOMMENDATIONS to help Turkey's further economic progress are made in a report of a mission sent to the country under the sponsorship of the International Bank for Reconstruction and Development in collaboration with the Government of Turkey. Although industrialisation, in the opinion of the mission, is a desirable goal, agriculture must be the base for further development since higher farm income means higher national income and bigger markets for industrial goods. Conservation and better maintenance of plant and equipment, and the more efficient use of existing resources is regarded as being equally important with the actual expansion of resources. The report anticipates a declining level of government investment in industry and mining, but an increasing level of investment in power, since greater power facilities are essential to private expansion, but are not likely to be privately financed to any great extent. Mr. Theodore J. Kauffeld, Consulting Engineer and President of Devenco, Inc., U.S.A., was the specialist in energy and power on the twelve-member mission.

Sweden's Power Supply

ONLY about five per cent. of the rural homes of Sweden are now without electricity, according to an announcement in the Anglo-Swedish Review. A report on the country's power supplies shows that power consumed in Sweden during last year amounted to 18,300 million kWh, corresponding to 2,600 kWh per inhabitant. The completion of a number of hydro-electric power plants now under construction will bring the total capacity up to nearly 25,000 million kWh, including a five per cent. additional potential of steam generated power a year towards the end of 1954. About 50,000 rural homes still remain to be connected up.

St. Lawrence Dual Project

THE interest of Canada and the United States in the big plan for utilising the St. Lawrence seaway to provide power for both countries has been revived again during the past few months, with sharply contrasting viewpoints on desirability and practicability. New discoveries of mineral wealth and the possibilities of the development of nuclear power have each played an important part in the formation of public opinion on the project. The United States Secretary of State (Mr. Acheson) and General Marshall, U.S. Secretary for Defence, are two of the leading figures in that country who have signified their support of the scheme, an attitude no doubt contributing largely to the introduction earlier this year into the U.S. Senate of a resolution in its favour.

Power and Transport

IT would be a dual power and navigational project, for the authors envisage construction of a deep water channel for navigation from the eastern end of the mouth of the river to the Great Lakes, while the development of hydro-electric power is calculated to generate about two million additional horse power, to be shared in equal proportions between New York State and the State of Ontario on the other side of the river. The Bill now introduced in Washington provides for New York State to purchase works on the United States side for power development, but there is division of views about the construction of the navigational channel. Factors operating here are, first, the decline in high-grade iron ore supplies from Minnesota and, on the other side, the large-scale development of similar deposits in the region of Labrador, which could be shipped up river by the proposed new channel. These plans, of course, are bound up with the all-prevailing problem of defence. Short-term developments in the international situation therefore may well constitute the deciding point for the entire scheme.

Hydro-Electric Researches in France

The hydraulic laboratories of the Ecole Nationale Supérieure d'Electrotechnique et d'Hydraulique de Toulouse were founded in 1918 by Professor C. Camichel, Membre de l' Institut who directed them for more than twenty years. In this article L. Escande, Professor at the Faculté des Sciences, Director of the Ecole Nationale Supérieure d' Electrotechnique et d' Hydraulique de Toulouse; Consulting Engineer (I.E.T.) surveys some of the work being carried out in the laboratories.

THE hydraulic laboratories of the Ecole Nationale Supérieure d'Electrotechnique et d'Hydraulique de Toulouse, some of which are at the School itself and the others some 2 kilometres away at Banleve, on the Garonne, are provided with the most up-to-date instruments and equipment and are distinguished by characteristics which place them in the front rank of the hydraulic laboratories of the world. The facilities include a tower 30 m. (99 ft.) high and cross section of 20 sq. m. (215 sq. ft.), an above-ground reservoir 6 m. (20 ft.) high and 20 sq. m. (215 sq. ft.) section (Fig. 1), basins of large capacity, channels and pipes of all sizes, numerous pumps giving circulation deliveries with a total of 2,000 litres per sec. (440 gal. per sec.) observation channels and pipes, etc. Briefly, the Banleve establishment is claimed to be the only hydraulic laboratory in the world possessing simultaneously:—

(1) An area of level ground exceeding 1 hectare (2·5 acres) for large reduced-scale models (Fig. 2).

(2) A calibrating basin with a wet section of 4 m. (13·1 ft.) wide, 3·50 m. (11·5 ft.) deep and 117 m. (384 ft.) long (Fig. 4).

(3) A wind tunnel with an air stream of 2·40 m. (7·9 ft.) diameter and a velocity of 40 m. per sec. (131 ft. per sec.) (Fig. 5).

(4) Two large channels, one straight, 117 m. (304 ft.) long, and with an internal section of 14 sq. m. (150 sq. ft.) and the other with varying sections and elbows; these two channels are fed by the natural fall of the Garonne and gravity flow is controlled by sluices, the discharge of each channel exceeding 20 cu.m. per sec. (4,400 gal. per sec.) (Fig. 6).

The laboratory at Anthony Falls in the U.S.A. which is also supplied from a natural fall, is the only one with a comparable flow.

Since 1924, the laboratories have had to study with the help of small-scale models many important schemes executed in France or abroad. Within the scope of this article, we can hardly even enumerate the 75 schemes studied in this way, but it may be said that most of the models were constructed on a scale ranging between 1/25 and 1/50, 1/40 being the value most usually adopted. These investigations have made possible remarkable achievements in regard to safety, economy and efficiency.

Range of Researches

It is quite impossible, in this article, to mention all the investigations carried out, since the inception of these laboratories, by the scientists and engineers who have worked here under the inspiration and guidance of M. Camichel and among whom the author would mention Messrs. Eydoux, Foch, Ledoux, Pichot, Ricaud, Dupin, Teissie-Solier, Crausse, Baubiac, Boujon, Castagnetto, Otsubo, Laszlofly, Castex and Nougaro, but an idea of the range of these investigations is conveyed by the statement that the work carried out by the author of this article, individually or in collaboration, has given rise to more than 210 publications, including 13 which have been put on sale in bookshops. In these circumstances we must confine ourselves to mentioning the fundamental work of M. Camichel on water hammer and the remarkable chronophotographic method he devised of measuring velocities, to the researches of MM. Dupin and Tessie-Solier on vortices and to a few of our own investigations, some of which are still in hand.

Researches on Similitude

From the theoretical point of view, we will confine ourselves to the general classification of the various types of flow, to the similitude applicable in turbulent conditions, to demonstrating the non-similitude of air-entrainment phenomena, to determining the degree of roughness to be adopted for the models with or without distortion, and to the relation between the sand dunes of the desert and the undulations modelled by water on sand (Fig. 7).

Theoretical considerations indicate that in most practical applications precise similitude does not exist. The technique of tests on models is therefore based on approximations of which the importance must be determined in each case. We have followed this task systematically, striving to extend the useful range to a maximum both by utilising the facilities offered by the laboratory and by making full-scale determinations at large industrial works.

These studies have been directed to the most varied types of flow; resistance of submerged bodies, wakes, orifices, eddies, vortices, viscous fluids, constricted and unconstricted weirs, floodwater evacuation, piers and dam sluices, pressure pipes, collecting aqueducts at the Miegebat station, penstock pressure release at the Carcanet station, fish ladders, aqueducts for filling the large dry dock at Le Havre (Figs. 8 and 9), determining and plotting the currents found at the Vives Eaux dam on the Seine, air entrainment, balancing chambers, etc.

Velocity and Discharge Measurements

The systematic employment of M. Camichel's chronophotographic method has permitted the extension of its application to the field of turbulence,

Fig. 1. Hydraulic laboratories of the Ecole Nationale Supérieure d'Electrotechnique et d'Hydraulique de Toulouse at Banleve

to confirm the non-rotational character of numerous types of flow, as well as to the improvement of the Pitot tube. The utilisation of this tube with a compensating pump has led to a linear graduation and a high degree of sensitiveness at low velocities. We will also mention the researches of inclined weirs and on flow meters—the influence of weir inclination on the rate of approach, the influence of a wall or of a free surface, on the influence of calibration of a meter under too restricted conditions or calibration by paddle wheel.

Dams, Weirs and Flood-Water Channels

These researches (see Fig. 10) have revealed the non-rotational character of the movement apart from the boundary layer in contact with the facing stonework, the justification of Prasil's graphic construction (Figs. 11 and 12), the frequent existence of depressions, the presence of a horizontal-axis eddy at the foot of the upstream wall, as well as the distribution of the velocities, the pressures and the energy in the liquid mass and along the sill.

The study of lateral constrictions has demon-

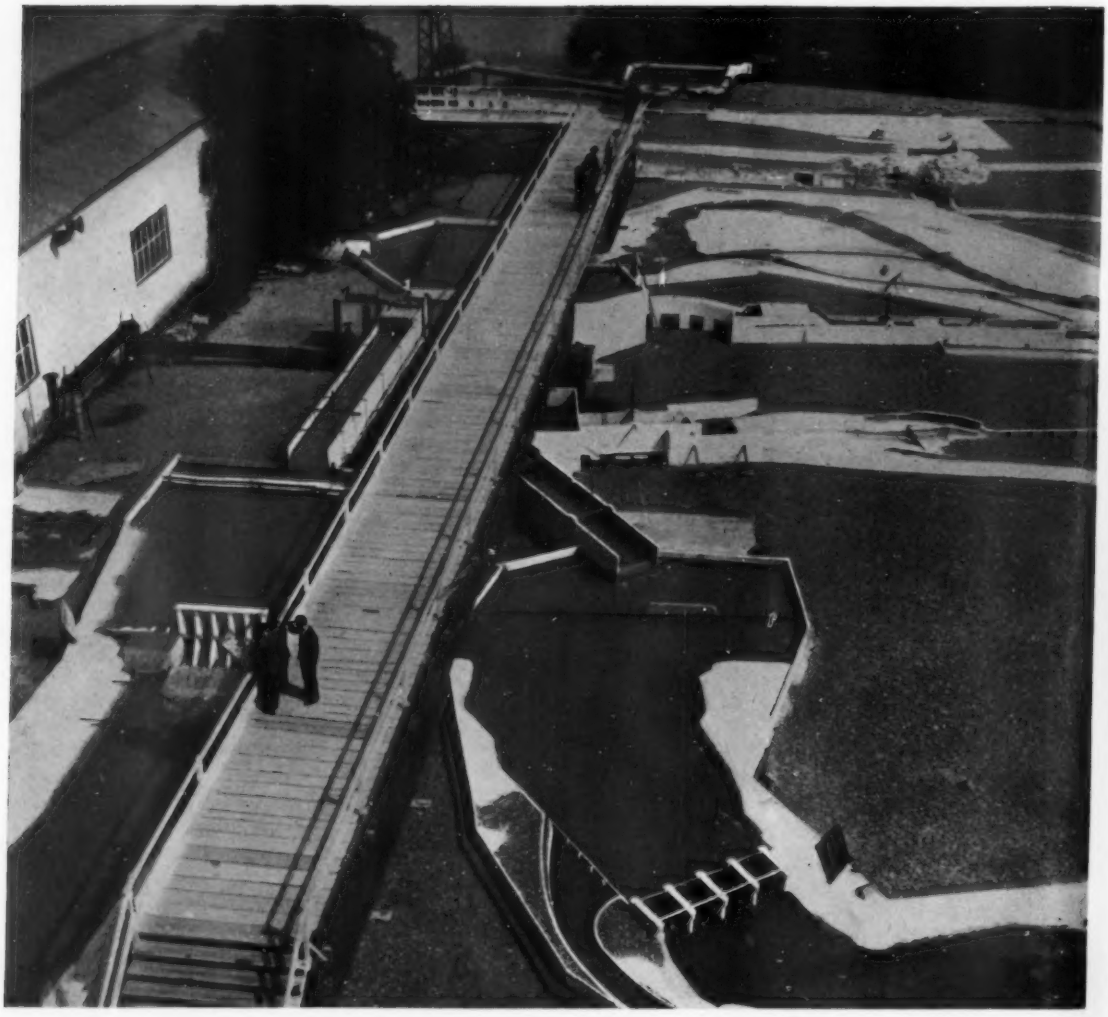

Fig. 2 (above). Level area for large reduced-scale models. The space available exceeds 1 hectare (2·5 acres)

Fig. 3. Aerial view showing location of the Banleve laboratory on the river Garonne

strated the advantage of abutments with pronounced forward upstream rake, and of streamlined section by means of which the effect of the constriction is practically eliminated. The downstream part of the abutments can be dispensed with without causing any trouble to the flow, as evidenced in Fig. 13.

Finally, we would mention the pulsation of the weir discharge that sometimes occurs when there is a downstream standing wave. This takes place whether the bed is resistant or liable to scouring, the phenomenon in the latter case being accompanied by corrugation of the bed.

Our first investigations on the Creager crest, the best sec-

Fig. 4. View of calibrating basin

tion in the absence of suction, have just been completed—though the results have not yet been published—by the study of Creager sills operating under suction and under a head exceeding that corresponding to that for which they were designed; within certain limits, which we have determined, these flattened Creager crests ensure very stable operation, together with a high coefficient of discharge ($m = 0{\cdot}54$). Investigations now in hand give every indication that we may shortly develop perfectly stable sills, based on entirely new principles, having a considerably higher coefficient of discharge.

The case of dams surmounted by discharge sluices or sector gates has also been studied exhaustively (Figs. 15 and 16).

Adjustable Weirs

The operation of partially raised sluices has been studied theoretically and experimentally (Fig. 14). The basic formulæ thus established have been expressed by graphs easily applicable whether the movement is flooded, critical or exposed. Some curious cases of multiple and indefinite solutions have been discovered where there is a sudden lowering of the floor of the channel on the downstream side of the weir. In certain conditions for the same sluice opening and for given upstream and downstream levels, the discharge can have two different values, depending on the configuration assumed by the overflow. Finally, as with weirs, an alternating movement of the sluice discharge is sometimes observed.

The simultaneous operation of adjustable crest gates and bottom sluices, which has been studied in

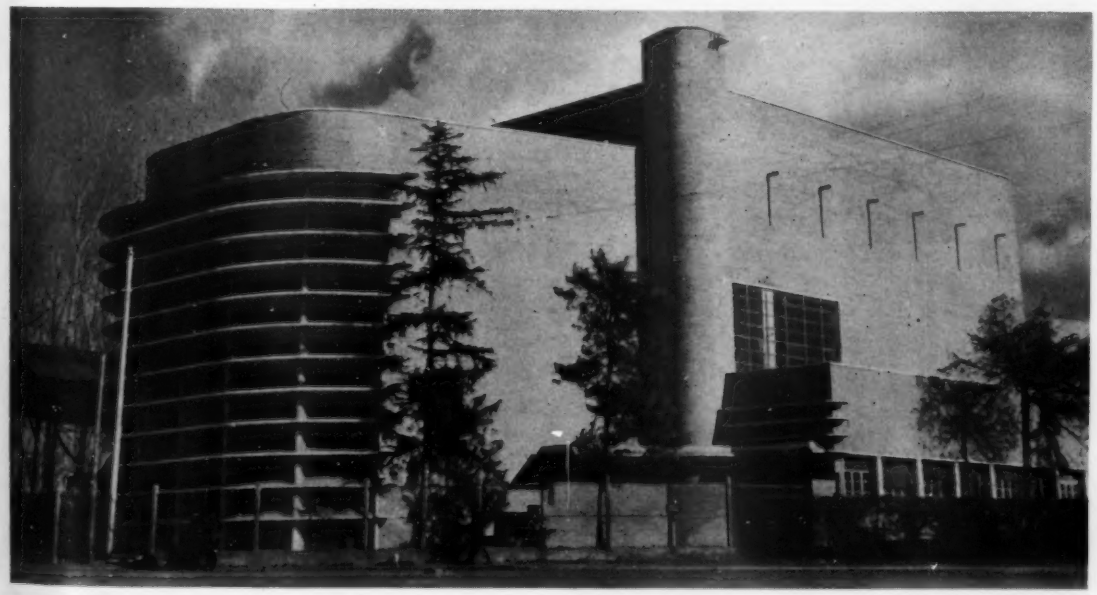

Fig. 5. Exterior view of the wind-tunnel building

great detail, can give rise to a particularly dangerous pulsation when aeration is absent or insufficient. Fig. 17 indicates some aspects of these pulsations, the amplitude of which would be several metres with a periodicity of only 2 sec. for a sluice 12 m. high; the violence of this action would be sufficient to destroy the structure.

We also mention the advantage of streamlined piers, which give greatly reduced losses, the formulæ giving the fall in level caused by flow through a passageway, the possibility of eddy resonance arising behind round piers and the transverse movement of the water surface which may result, and finally certain anomalies due to current interference, evidenced by the fact that a passageway 20 m. wide can have a discharge per metre run nearly 30 per cent. greater than that of one three times as wide under the same conditions.

Excess Pressure in Pressure Pipes

Among the numerous theoretical investigations carried out in this field, we mention the following which have only become possible by methods of calculation that have been specially established for each case :

(1) A theoretical study of the excess pressure generated in a pipeline by a non-sinusoidal periodical disturbance maintained at the downstream end of the pipeline.

(2) A theoretical study of the excess pressure caused by the closing of a balanced-disc valve placed at the downstream end of a pipeline, following a breakdown of the control equipment. This investigation, carried out after the accident which occurred at the works at Sainte - Etienne - Cantales, emphasised the need for a shock-absorbing closing device connected with the disc valve.

(3) A theoretical study of the law controlling the closing of a servomotor-operated

Fig. 6. Test channel 304 ft. long by 150 sq. ft. section

Fig. 7. Undulations in desert sand (above) and foreshore sand (below)

Fig. 8. Dry dock at le Havre

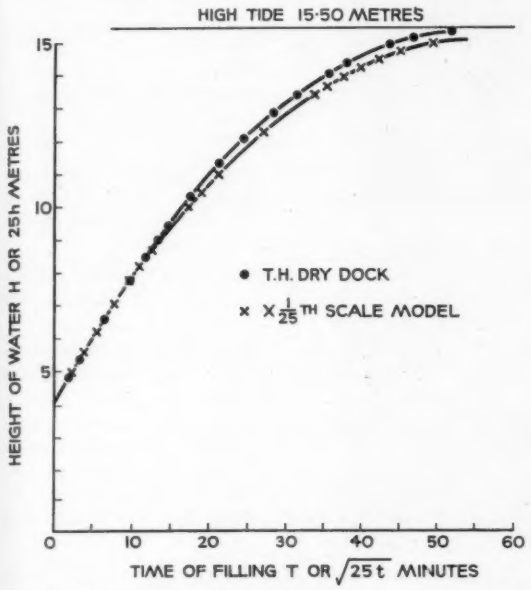

Fig. 9. Curves showing the filling of the actual dock and of a 1/25 scale model. In the actual dock the time T is taken from the moment at which H passes the 4 m. mark

balanced-disc valve placed at the downstream end of a pipeline, taking into account the resulting water-hammer effect, and the determination of the corresponding excess pressure. This investigation carried out in connection with the inlet sluices of the auxiliary units installed at the Genissiat station demonstrated the considerable influence played by the surge arrester at the end of the closing operation on the maximum excess pressure attained.

(4) A theoretical study of the water-hammer effect generated in the pipeline and in the tailrace tunnel of an installation where the tailrace channel acts under head without the interposition of a draught tube. This investigation, originally instigated in connection with a proposed installation on the Garonne by the Energie Industrielle, was subsequently and effectively applied by us, to the calculation of the equipment for the installations at Paolo Afonso, Brazil, and at Bort-les-Argues, France.

(5) A theoretical study of excess pressures arising from the separate or simultaneous operation of the inlet sluice, the control valve and the guide vanes of a turbine. This work was carried out in connection with the construction of the Genissiat station; it has allowed us to arrive at a particularly clear conclusion in the most general case, whether there is an anti-vacuum valve or air escape valve or not on the pipeline leading to the turbine; in all cases the highest excess pressure is due simply and solely to the closing of the guide vanes, the other closing devices remaining open. We have thus demonstrated that practically speaking no real problem arises from water hammer in the pipeline.

(6) A theoretical study of excess pressures arising in an inlet system where the surge chamber is connected to the common point on the inlet channel and the pipeline by a tunnel of considerable length. This investigation, carried out in connection with the installation at Brevieres, has allowed us to establish that the surge chamber, although amply dimensioned and very expensive, allowed an excess pressure to penetrate into the inlet channel, which, far from being negligible, attained half the maximum water-hammer effect experienced at the guide vanes. This study determined the designer to adopt a solution eliminating the surge chamber.

(7) A theoretical determination of the closing operations producing the maximum excess pressures, and the values thus attained by the water-hammer, in the case of closing devices giving a bilinear

Fig. 10. Test rig for weirs

Fig. 11. Composite photograph of weir discharge

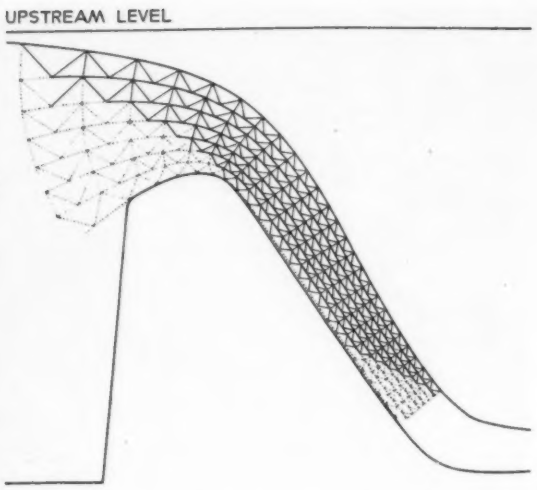

Fig. 12. Prazil's construction for weir discharge

closing law. This study was carried out in connection with the Brevieres station, for which apparatus of this type had been adopted, after abandoning the surge chamber, and has permitted generalisation from the results obtained by M. Gariel, in the case of a linear closing.

(8) A theoretical study of excess pressures transmitted from the pipeline to the turbine inlet in which the surge chamber has either a constriction at the lower end, or a connecting pipe, or both. This investigation has resulted in a definite solution of a problem which has worried specialists ever since the adoption of the constriction arrangement, deemed by many to be capable of transmitting dangerous water-hammer effects. Our investigation has made it possible to demonstrate that for all normal turbine operations the excess pressure transmitted by constriction is negligible; in the case of excess pressures due to an accident, the water-hammer effect transmitted can be calculated by a formula which we have established and remains acceptable, and in all cases is appreciably less than that which would be transmitted under the same conditions by a surge chamber equipped with a connecting pipe some few metres long—an arrangement which no technologist formerly suspected was dangerous.

(9) Observations on the very serious errors which can result for the upstream part of a multiple high-head pipeline, from a calculation of the excess pressure based on the consideration of assumed velocity of propagation. This study has yielded an explanation for certain phenomena noted in the upper portion of the pressure pipe of the Artigues station.

Surge Chambers

We have treated this question specially and have published two papers on surge chambers. We have applied the results obtained to the calculation of the surge chambers of 18 large installations.

The following are some points, briefly stated, which summarise the essentials of our contribution to this subject:—

(1) A theoretical study of the oscillations in an inlet pipe with two surge chambers in series, neglecting the head losses.

(2) An experimental study of the water oscillations in ordinary surge chambers following instantaneous closing or opening of the sluice; comparison with the classic formulæ, degree of approximation obtained and security resulting from the application of these formulæ.

(3) Experiments with partial closing, carried out at the Gripp station in the Pyrenees.

(4) An experimental study of overflow-type surge chambers, showing the magnitude of the errors

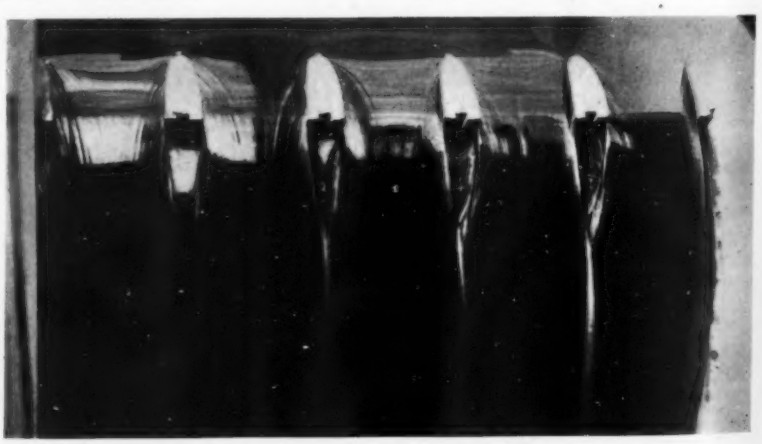

Fig. 13. Model showing action of interrupted abutments

resulting from the approximate method of calculation generally used for the determination of the maximum overfall discharge.

(5) A theoretical and experimental study of surge-chamber oscillations resulting from rhythmic movements of the guide vanes. This investigation has stressed the fact that the amplitude of oscillations due to isolated operations of closing or opening is considerably exceeded when these oscillations are superimposed on pre-existing oscillations; we have thus demonstrated that it is essential to take into account in our calculations this superimposition of oscillations, particularly in the case of long inlet channels, corresponding to a high periodicity of oscillation (18 minutes at the Malgovert station).

(6) Theoretical and experimental studies on surge chambers with constriction at the lower end. These experiments were made on laboratory models (Fig. 18) and on the Artigues surge chamber which we had designed and which was specially equipped for this purpose. Independently of the remarkable agreement between the theory and the results emanating from these researches (Fig. 19), a very important point was established: we have demonstrated that operations of a certain duration cause oscillations of an amplitude distinctly greater than those arising from instantaneous operations, which were alone taken into consideration formerly for calculating the dimensions of the works.

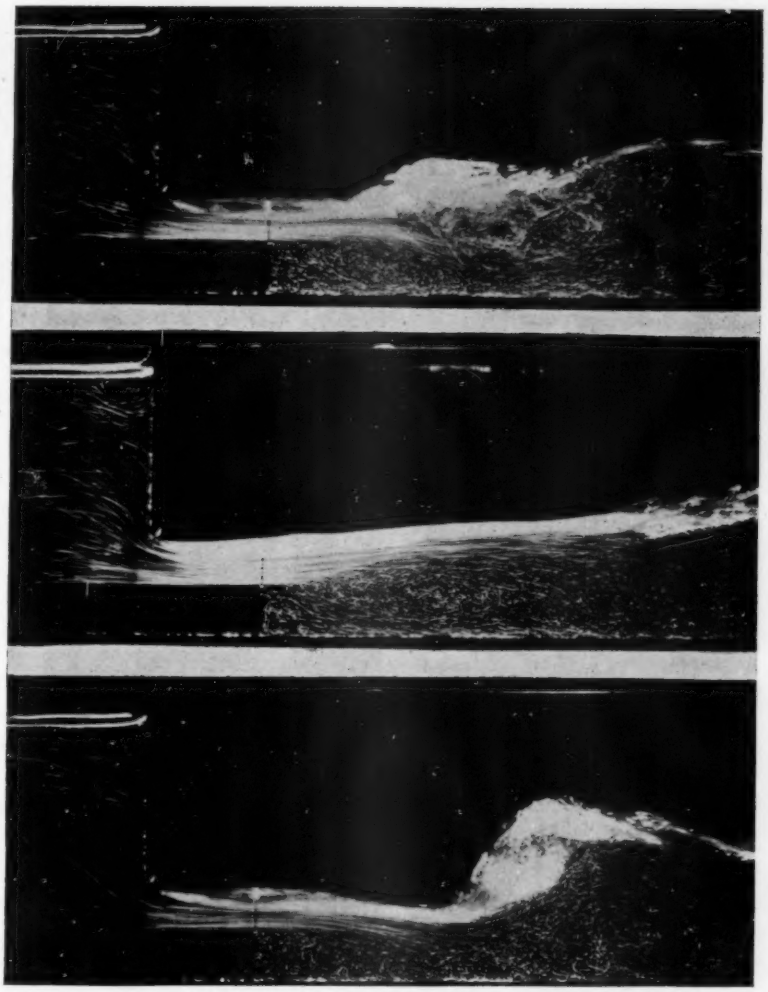

Fig. 14. Operation of partially raised sluice

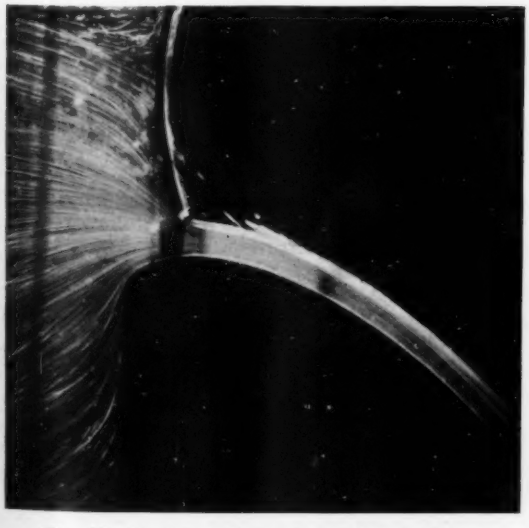

Fig. 15. Discharge through a sector gate

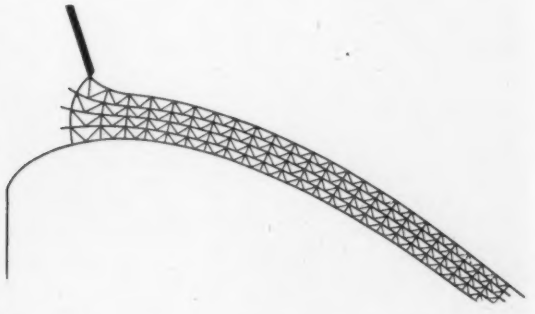

Fig. 16. Prazil's construction for discharge through a sector gate

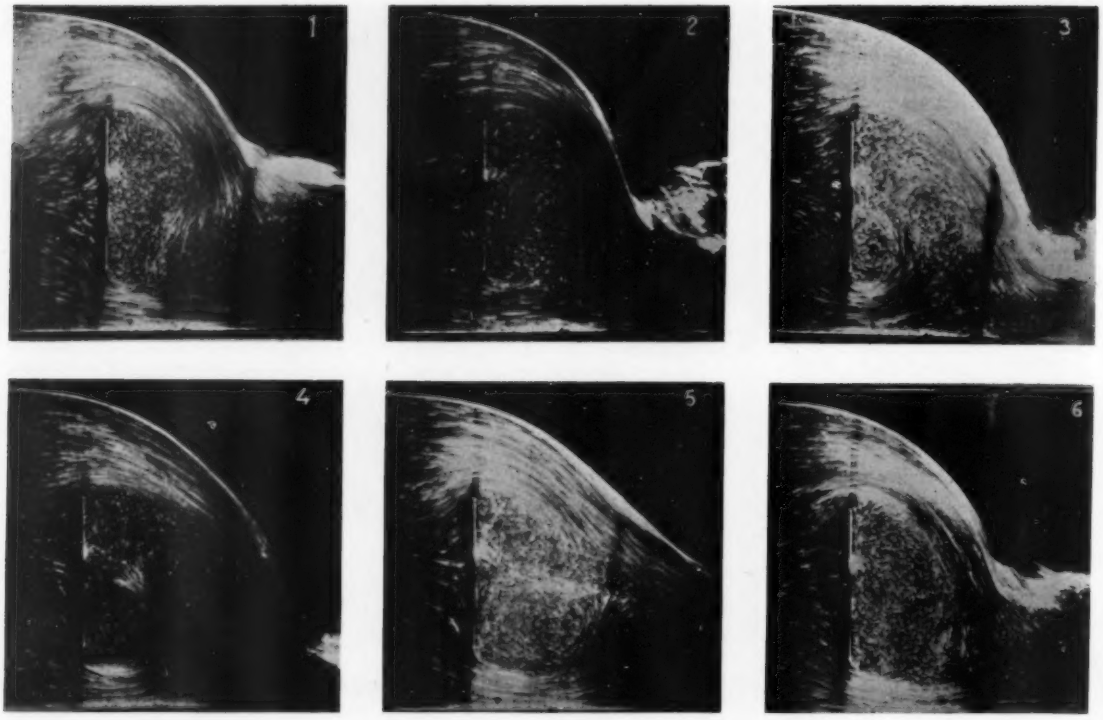

Fig. 17. Pulsations due to simultaneous operation of adjustable crest gates and bottom sluice

(7) A study of complex systems of feed waters from a number of lakes leading to the same surge chamber. We have supplied the general methods and the necessary formulæ for the determination of the characteristics of a single supply aqueduct, equivalent to the complex system under consideration in the absence of head losses or when taking these into account. This study has been made for all possible cases (aqueduct ending directly at the surge chamber, or coupled at the same single point or at several distinct points at any distance from this work, branched channels . . . etc.). This method, which was established in the first place for the Aston station and utilised for the Bioges station is constantly employed at the present time in the study of large projects collecting the hydraulic resources of a whole region to a single works.

Fig. 18. Model of surge chamber

(8) A theoretical study of the influence of the variations in head resulting from water-level oscillations in a surge chamber on the amplitude of these oscillations, in the case of constant power regulation.

(9) New methods for the calculation of surge chambers by means of differential or by semi-graphical methods. Applications of these methods to the solution of numerous problems, relating in particular to surge chambers, simple or multiple, of constant or variable section, with or without constriction, overflow-type chambers and chambers of constant or variable section, with or without overflow, with or without a lower constriction, in series on a single supply channel. Experimental confirmation of the application of the differential and semi-graphical methods to the study of various oscillation phenomena in surge chambers with constant or variable sections, with or without constriction at the lower end.

(10) A theoretical study of the oscillations in a chamber of variable horizontal section, in cases where the head losses are negligible.

(11) Calculation of the oscillations in a surge chamber fed simultaneously by an open channel and by a pipeline under a head.
(12) Calculation of surge chambers, with or wi.hout constriction at the lower end, in which the supply channel collects various contributing supplies by

The essential aim of a modern hydraulic laboratory, in our opinion at least, should be to derive the terms of multiple problems, from questions put by industry, frequently of great importance, and to attempt to find a definite solution for the widest application based simultaneously on theory and experiment.

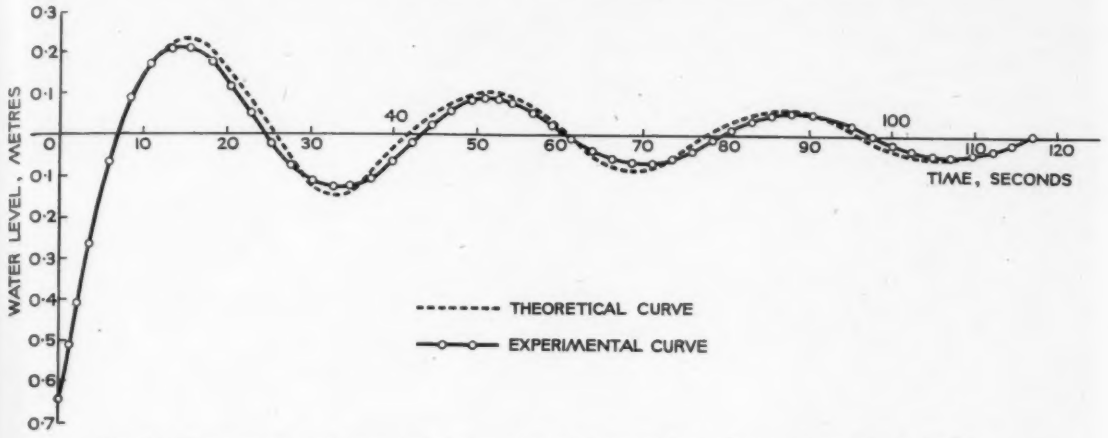

Fig. 19. Theoretical and experimental curves of fluctuations in surge chambers following instantaneous closure of the turbine inlet valve

small-diameter shafts, with or without consideration of the losses of head. This study, carried out in the first instance in connection with the design of the station at Olette, is used at the present time by us for the calculation of the extremely complex works of catchment and delivery to the Cap-de-Long installation.

Other Investigations

In the preceding brief review, we have left aside numerous questions which have however given rise to important researches. We mention some of these:

Non-turbulent wakes.
Eddy pipes and vortices.
Underground flood-water dischargers.
Flow through a grille.
Flow between bridge piers.
Movement at the entrance to an open channel.
The flow of water in an elbow of a pipe or channel.
Certain measuring devices for the discharge of pipes and conduits.
A simple arrangement for recuperation of the kinetic energy at the downstream end of a conduit.
A discharge limiter functioning by cavitation at the outlet of a pipe.
Turbulence and Joule's experiment.
The correction to be applied to the calculation deduced from the principle of "maximum discharge."

Conclusion

However incomplete the preceding summary may be, and although it only relates to one portion of the work, we hope that it may give an overall appreciation of the researches carried out by the Toulouse hydraulic laboratories. The spirit which has constantly inspired this work should be borne in mind even more than the details of these investigations.

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High-frequency Vibration. Adequately-illustrated pamphlets received from Westool Limited discuss the advantages of their high-frequency vibration tables for both concrete consolidation and research, and their high-frequency hand-type vibrators.

Terminal Link Blocks. Where light and heavy engineering combine, as in the remote control of power networks, one of the problems encountered is that of joining V.I.R. cabling to single-core telephone wiring and to this end Standard Telephones & Cables Limited have put on the market a new standard terminal block which, besides carrying terminals, also carries link sockets and soldering tags, thus enabling properly engineered terminations to be made in all conditions.

Fig. 1. La Cave scheme with aggregate plant constructional camp in foreground

Water Power Resources of Canada

The Water Resources Division, Department of Resources and Development, has presented its latest review of the water power resources of Canada.

THE water powers of Canada, although only partly developed, have exercised a marked influence on the economic development of the country throughout the present century, during which a gradual change has occurred from an economy based largely on agriculture to one increasingly dependent upon industrial operations. This transition, closely coinciding with the growth of water-power development, has been greatly accelerated in recent years. The close relationship between water power and industry is particularly evident in the central provinces which, although lacking in indigenous coal, have become the more highly industrialized regions of the country. Also in recent years, British Columbia, which is rich in potential water power, has been making rapid industrial progress coincident with water-power development. From the pronounced activity in hydro-electric construction during 1950 it may be concluded that this general trend is continuing. A total of 962,275 h.p. of new capacity was brought into operation during the year and a huge programme of construction is under way which will rapidly increase the hydro-electric generating capacity of the country.

Total Available and Developed Water Power

Table I gives the total water-power resources of Canada, and the present total capacity of all water-power plants in the country. The estimates of available power are revised from time to time as more precise stream-flow records are accumulated and as more detailed information on potential power sites is secured; as defined below, estimates are made on the bases of ordinary-minimum flow and dependable-maximum flow. The totals of developed power are derived from the manufacturers' ratings, if this information is available. Adjustments of the totals are

made to allow for the dismantling of old plants and for corrections in listed plant capacities as more accurate information is received.

TABLE I — AVAILABLE AND DEVELOPED WATER POWER IN CANADA, 1950

Province or Territory	Available 24-hour power at 80% efficiency		Capacity Installed h.p.
	At Ordinary Min. Flow —h.p.	At Ordinary Six Months Flow—h.p.	
1	2	3	4
British Columbia	7,023,000	10,998,000	1,284,208
Yukon and N.W.T.	382,500	814,000	28,450
Alberta	507,800	1,258,000	107,225
Saskatchewan	542,000	1,082,000	111,835
Manitoba	3,309,000	5,344,000	595,200
Ontario	5,407,200	7,261,000	3,513,840
Quebec	8,459,000	13,064,000	6,372,812
New Brunswick	123,000	334,000	133,111
Nova Scotia	25,500	156,000	150,960
Prince Edward Is.	500	3,000	2,299
Newfoundland	1,135,000	2,585,000	262,810
Canada	26,914,500	42,899,000	12,562,750

In Table I, Col. 2 lists the estimated continuous power ordinarily available at periods of low discharge under existing conditions of river flow; the "Ordinary-Minimum Flow" is based on the average of the mean flows for the two lowest periods of seven consecutive days in each year covered by the period of record. Estimates of dependable-maximum power, Col. 3, are based upon the "Ordinary-Six-Months Flow" which is the computed dependable stream flow usually available for at least six months in the year under existing flow conditions. On rivers for which there are no specific discharge records, estimates of flow are made from all available pertinent information relating to run-off in the area.

With respect to hydraulic head, the figures of Cols. 2 and 3 are based upon the actual drop, or feasible concentration of head, which has been measured (or at least carefully estimated) at existing falls, rapids and known power sites; no consideration has been given to possible economic concentrations of head on rivers and streams of gradual gradient, except at those locations where the feasible head has been definitely established by field investigation. Many unrecorded power sites exist on rivers and streams throughout the country, particularly in the less explored northern districts, the capacity of which will be subject to tabulation only as more detailed survey work is completed. Thus as regards both the total number of sites and the possible head at each site, the listed figures of available power represent only the minimum possibilities.

At fully developed sites, the installed capacity is usually somewhat in excess of the power available at ordinary-six-months flow, although the maximum economic installation at any one site can be determined only by careful consideration of all conditions and circumstances pertinent to its individual development. In some cases, an original deficiency in power during periods of lower flow is overcome by the use of storage dams; in others, by interconnection with other plants operating under different load conditions or which are located on other streams having different flow characteristics; or by auxiliary power from fuel plants. A tabulation of the installed capacity of a number of typical plants across Canada, located on rivers for which adequate discharge records are available, shows that these plants have an installed turbine capacity which on the average is 30 per cent. greater than the power equivalent of the six-months flow at their sites.

Because excess capacity is usually installed at developed sites, the figures of Col. 4 are not directly comparable with those of Col. 3; that is, in computing the relationship between the figures of presently developed power and those of total resources, Col. 3 should be increased by 30 per cent. On this basis, the present total turbine installation of 12,562,750 h.p. indicates the development of less than 23 per cent. of the recorded water-power resources of Canada.

Fig. 2. Aerial view of Chenaux dam and generating station

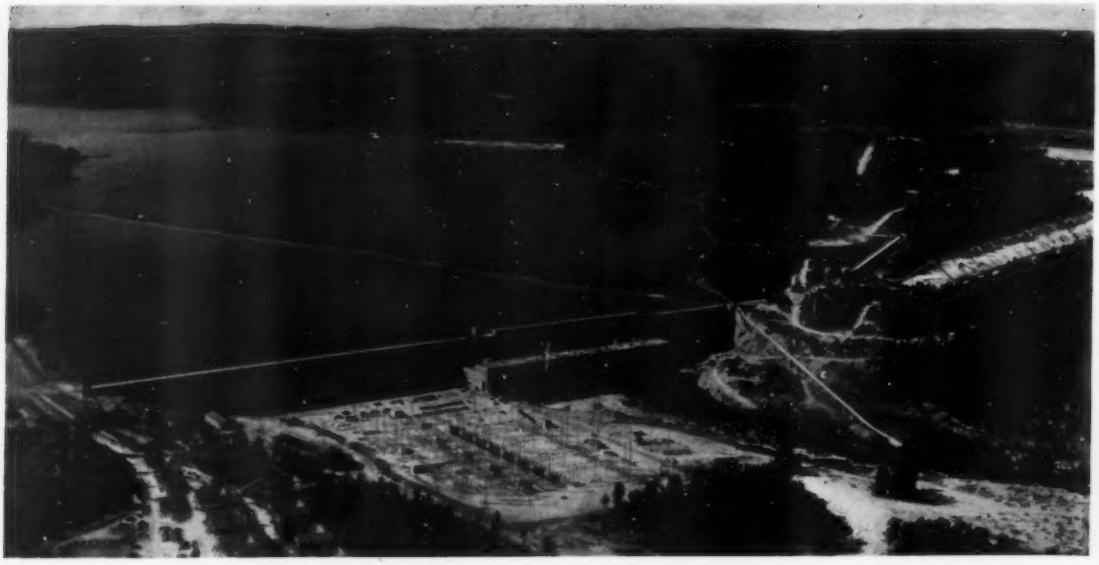


Fig. 3. Des Joachim dam and generating station

Also, the figures of maximum available power, Col. 3, showing a total of 42,899,000 h.p., may be said to be conservative, as already recorded water-power resources of Canada will permit of an economic turbine installation of more than 55,000,000 h.p.

Provincial Distribution of Water Power

An analysis of the provincial distribution of Canada's potential and developed water powers, as listed in the above Table I, shows that, on the whole, important resources are well distributed throughout the country and that, even at the present stage of development, considerable blocks of power are being produced in all provinces except Prince Edward Island where resources are small. The provinces of Ontario and Quebec contain nearly 47 per cent. of the total potential power and more than 78 per cent. of the developed power, more than 37 per cent. of their presently recorded total reserves being now developed; by use of water power, these central provinces, although lacking in indigenous coal, have become highly industrialized. As the development of Canada's natural resources proceeds, the fortunate incidence of water power in proximity to mineral deposits, pulpwood and other natural resources is becoming more widely realized.

British Columbia, traversed by three distinct mountain ranges and with, on the whole, a high rate of precipitation, has many mountainous rivers which offer opportunity for power development. The province ranks second in available resources and is exceeded only by Quebec and Ontario in installed capacity. Practically all present developments are located in the southern portion of the province, the largest, 186,000 h.p., being the Bridge River Plant of the British Columbia Electric Railway Company, Limited. The British Columbia Power Commission, organized in 1945, is becoming increasingly important as a power-producing and distributing agency.

The potentialities of the Yukon and Northwest Territories, although considerable, are so remote from markets as to limit their present commercial development to local mining uses. However, owing to lack of native fuel and to transportation difficulties, they are of special importance in the development of such mining areas as Yellowknife, Northwest Territories, and Mayo, Yukon Territory.

In Alberta, the larger hydraulic developments, from which Calgary Power Limited serves a large part of the southern portion of the province, are located on the Bow River and tributaries. The greater part of water-power resources is located in the northern half of the province, rather remote from present centres of population.

In Saskatchewan, water-power developments are confined to mining uses in the northern areas. The transmission network of the Saskatchewan Power Corporation of the Provincial Government, serving the more settled areas, is supplied by fuel-power plants, both Saskatchewan and Alberta having large reserves of coal, natural gas and oil.

Of the Prairie Provinces, Manitoba has the largest water-power resources, there being great potential power on the Winnipeg, Nelson and Churchill Rivers. Present developments are practically all located on the Winnipeg River to serve Winnipeg, adjacent municipalities and the transmission network of the Manitoba Power Commission. The Commission is at present serving some 300 municipalities and is carrying out a vigorous programme of rural electrification, it being estimated that 21,400 farms were receiving service at the end of 1950.

Ontario has large resources, being exceeded in this respect only by Quebec and British Columbia. It has developed more than 37 per cent. of its potential and ranks second in power production among the provinces. The Hydro-Electric Power Commission of Ontario is the greatest power-producing and distributing organization in Canada; it operates 61 hydraulic generating stations with a total capacity of over 2,700,000 h.p., the largest being the Queenston plant on the Niagara river of 560,000 h.p.; in addition,

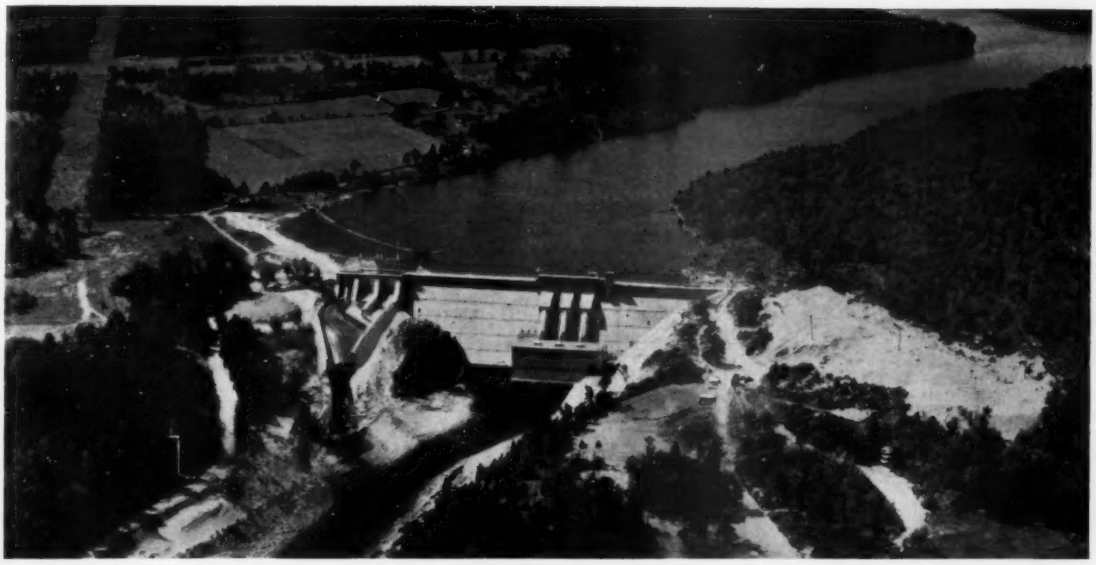


Fig. 4. Aerial view of the Stuartville dam and powerhouse

nearly 1,000,000 h.p. is purchased on contract. At the end of 1950, power was being supplied to more than 1,000 municipalities; rural electrification receives special consideration and approximately 114,500 farms are now being served.

The Province of Quebec is richest in water-power resources, containing more than 30 per cent. of the total recorded for Canada. It also ranks highest in developed power, its present installation of more than 6,000,000 h.p. being more than 50 per cent. of the total for all provinces and representing the development of more than 37 per cent. of its recorded resources. The Shipshaw Plant No. 2 of the Aluminium Company of Canada on the Saguenay River with an installed capacity of 1,200,000 h.p. is the largest in Canada and is one of the larger plants in the world. The Beauharnois No. 1 power-house of 742,000 h.p., on the St. Lawrence River near Montreal, which is operated by the Quebec Hydro-Electric Commission, also has a greater capacity than that of any individual plant in all other provinces. Power production in the province is greatly facilitated by the regulation of stream flow by the Quebec Streams Commission through the storage dams it operates or controls. Rural electrification has made good progress with about 68,000 of the 150,000 farms in the province now receiving service either from private companies or through the co-operative system; further extensions are being fostered by the Quebec Rural Electrification Bureau.

The water powers of the Maritime Provinces, although small in comparison with the resources of other provinces, constitute a valuable source of power. Both New Brunswick and Nova Scotia have numerous rivers upon which moderate power developments may be made within economic transmission distance of the principal cities and towns; other sites are advantageously situated for the utilization of timber and mineral resources. These provinces also are favoured with abundant indigenous coal supplies.

Owing to lack of stream-flow data, Newfoundland's water-power resources have been only tentatively evaluated. Present estimates of available power give a total of 2,585,000 h.p. On the island, while the rivers are short, topography and run-off conditions are favourable to power development; in Labrador, the Hamilton River has a high potential. Considerable development has taken place on the island where there are 18 plants with a total capacity of 262,810 h.p. The larger developments serve the pulp-and-paper industry, Bowaters Limited having a plant of 156,000 h.p. on the Humber River and the Anglo-Newfoundland Development Company having two plants on the Exploits River totalling 68,900 h.p.

Progress in Development during 1950

With a total of 962,275 h.p. of new capacity coming into operation, the year 1950 is outstanding. A large proportion of this new capacity is located in Ontario and represents the culmination of the post-war constructional programme undertaken by the Hydro-Electric Power Commission of Ontario. Other new plants and extensions which are under active construction are tentatively rated at 1,000,000 h.p. and those under preliminary construction or definitely planned at about 1,500,000 h.p. Although the demand for hydro-electric energy continued to grow during 1950, being more than eight per cent. greater than in 1949, power production was in general keeping pace with the increased demand.

The British Columbia Power Commission made good progress on its initial development at Whatshan Lake; here 33,000 h.p. will be developed in two units and operation was scheduled for April, 1951; ultimately, the plant capacity may be doubled. The 138 kV transmission line from the plant to Vernon, 140 miles, has been completed. The Commission also has under construction a development at Clowhom Falls, on the Clowhom River at the head of Salmon Arm; the initial installation, with operation expected in 1951, will consist of two units each of 2,000 h.p. On Vancouver Island construction is being under-

taken of a 132 kV transmission line from the John Hart plant on Campbell River to Duncan Bay. The British Columbia Electric Railway Company Limited has completed the installation, for peak-load purposes, of the third unit of 47,000 h.p. in its Ruskin plant. It also has undertaken the modernization of its Lake Buntzen No. 1 plant and will replace seven old units having a total capacity of 28,140 h.p., by one new unit rated at 70,000 h.p. Design and field work have been continued on a project at Jones Lake, about 15 miles east of Chilliwack, covering a development of 80,000 h.p. in a single unit under 2,000 ft. head. In the field of power distribution, an extensive programme of sub-station construction was carried out in Vancouver, in the Fraser Valley and on lower Vancouver Island. The double-circuit 132 kV transmission line from Nanaimo to the Victoria system was completed in October. The Aluminium Company of Canada Limited continued its investigations on the Nechako-Kitimat project and further studies are scheduled for 1951; under the proposed scheme, the development of an estimated 1,600,000 h.p. of firm capacity is envisaged. Two small additions to hydro-electric capacity in British Columbia were also made during the year: the Ashcroft Water and Electric Company installed a new unit of 325 h.p. in its plant on the Bonaparte River; Gilley Brothers Limited replaced an originally installed 500 h.p. water wheel, on the Pitt River, by a 550 h.p. hydro-electric plant.

In Yukon Territory, construction on the Mayo River of a development with an initial capacity of 3,000 h.p. was commenced by the Northwest Territories Power Commission, for serving the silver-lead mines in the district.

In Alberta, Calgary Power Limited completed a large part of its overall scheme covering the Spray Lakes power-and-storage development. Operation of the Spray plant of 62,000 h.p., a single unit under 900 ft. head, originally scheduled for December, 1950, was expected early in 1951. The Three Sisters plant of 3,600 h.p. is under construction for operation in June, 1951, and the Rundle plant of 23,000 h.p. for July, 1951. Also, an additional unit of 12,000 h.p. is being installed in the Kananaskis plant on the Bow River for 1951 operation. The company is making extensive additions to its transmission system including 132 kV lines under construction from the Ghost plant to Edmonton and from the Spray and Barrier plants to Coleman. Northern Utilities Limited are investigating a site on the Hart River, north of High Prairie, where perhaps 1,500 h.p. may be developed. Canadian Utilities Limited has installed an 800 kW diesel unit at Grand Prairie; eight fuel plants with a total capacity of 22,090 kW are now being operated.

The Saskatchewan Power Corporation, owned and operated by the Province, carried out extensions to its fuel-power central-electric plants by adding an 800 kW diesel unit at Unity and two 200 kW units at Kindersley. A 15,000 kW steam turbine is under installation at Estevan for operation early in 1951. The transmission network was expanded by adding about 213 miles of 69 kV line, 134 miles of 33 kV line and 234 miles of 24 kV line. Farm electrification is proceeding gradually with about 2,400 farms being given service in 1950.

In Manitoba, the Winnipeg Electric Company, at its Seven Sisters plant on the Winnipeg River, brought into operation in August the fifth unit of 37,500 h.p., which raises the total installed capacity to 187,500 h.p.; ultimately, a six unit may be installed. During the year, a two-circuit 110 kV line from the plant to Transcona was completed and also a new sub-station at Transcona. Good progress was achieved on the Pine Falls development of 114,000 h.p. by the Government of Manitoba; the dam has been partly completed, work is under way on the power-house and it is anticipated that two units of 19,000 h.p. each will be ready for service late in 1951. Sherritt-Gordon Mines is proceeding with a development of 7,000 h.p. on the Laurie River, a tributary of the Churchill River in northern Manitoba; during 1951 construction will be commenced on the power plant which is to be located about 14 miles below Russell Lake. The City of Winnipeg has begun construction on a new auxiliary steam plant, the first unit of 15,000 kW being scheduled for operation late in 1951; tenders have been called for a second unit of 25,000 kW for operation in 1953. The Manitoba Power Commission carried out extensive additions to its transmission and distribution system and during the year 4,400 farms were connected to the lines.

In Ontario, the Hydro-Electric Power Commission of Ontario completed a large part of its current programme. At the Des Joachims development on the Ottawa River, seven units each of 60,000 h.p. were placed in operation and the final eighth unit was nearing completion. At the Chenaux development, also on the Ottawa River, two units were operating in December and completion of the plant of eight units, each of 20,000 h.p., is scheduled for the summer of 1951. At the La Cave site, Ottawa River above Mattawa, clearing and railway re-location were well advanced and the dam, headworks and power-house were under active construction; three units each of 32,000 h.p. were expected to be in operation late in 1951 and 192,000 h.p. is scheduled to be in operation in 1952. The development of 56,000 h.p. in two units at the Tunnel site on the Mississagi River was completed in July and of 80,000 h.p. in two units at the Pine Portage site on the Nipigon River in September. The Commission is undertaking a new development of 600,000 h.p. in six units on the Niagara River; preliminary planning and investigations are well advanced and operation in 1954 is anticipated. In addition to its hydro-electric operations, the Commission also has under construction two large steam plants: 198,000 kW in three units at Windsor, with initial operation in 1951 and completion in 1952; 400,000 kW in four units at Toronto, with initial operation in 1951 and completion in 1953. Pending completion of these plants, five temporary steam plants are being operated with a total capacity of 61,000 kW. Extensive additions were made to the transmission and distribution systems of the Commission including 939 miles of 230 kV line and 547 miles of 115 kV line. In southern Ontario, good initial progress was made on the changeover from 25-cycle to 60-cycle operation. Independent of the activities of the Commission, other additions to capacity include: Town of Orillia, 3,750 h.p. in a new plant on the Muskoka River; Great Lakes Power Company, a new unit of 13,200 h.p. in its Michipicoten River plant; Abitibi Power and Paper Company, increased capacity of 4,350 h.p. due to modernisation of its Iroquois Falls plant on the Abitibi River.

The Quebec Hydro-Electric Power Commission

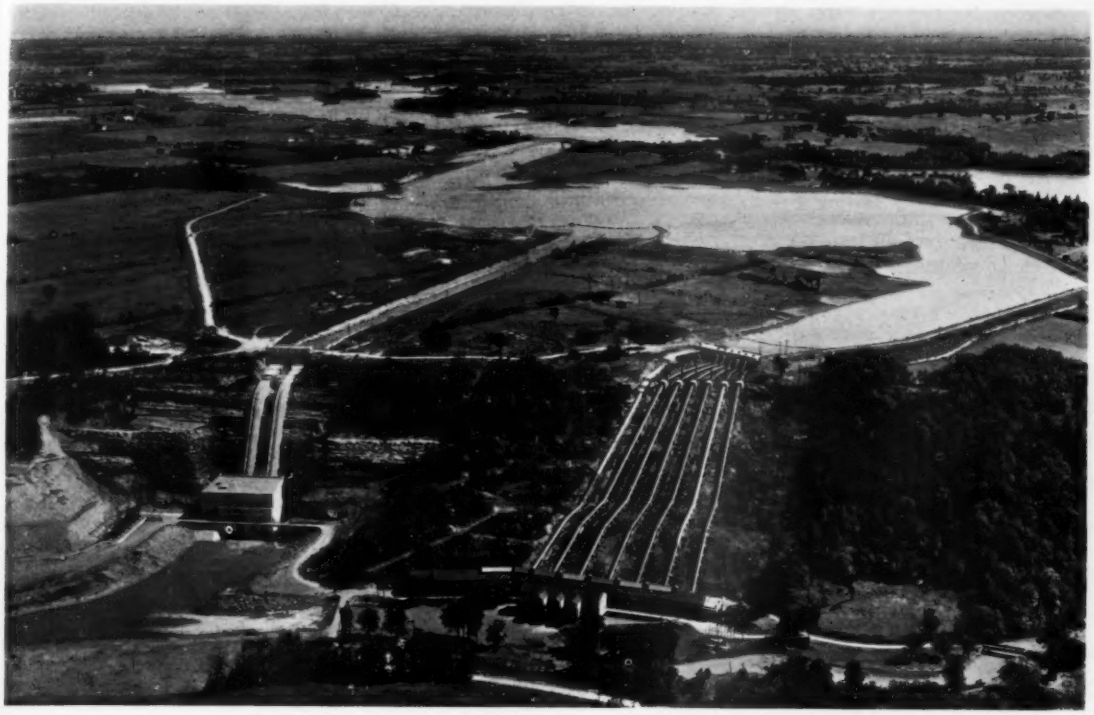


Fig. 5. Aerial view of the Decu plant, near Thorold, Ontario

brought into operation the first two units each of 55,000 h.p. in its new Beauharnois No. 2 power-house, St. Lawrence River; four additional units will be installed in 1951 and ultimate plant capacity is 660,000 h.p. Surveys are being completed covering the development of Rapids No. 1 and No. 2 on the upper Ottawa River. The Commission carried out extensive additions to its transmission and distribution systems including new high-voltage lines from Beauharnois to Montreal and from Cadillac to Amos; also new sub-stations in Montreal, Renault, Pandora and Amos. The Shawinigan Water and Power Company completed the installation of two units each of 65,000 h.p. in its new La Trenche plant on the St. Maurice River; an additional three units are scheduled for 1951 operation and ultimate capacity is 390,000 h.p. Extensions of the company's transmission lines included a 147 mile 220 kV line from La Trenche to Sorel via Three Rivers. The Aluminium Company of Canada has undertaken the development of 200,000 h.p. on the Peribonka River at Chute du Diable and the first unit of 50,000 h.p. is scheduled for operation by May, 1952. The Northern Quebec Company had under installation a new unit of 34,500 h.p. in its Quinze plant, upper Ottawa River, which will bring the total capacity to 84,500 h.p. The Quebec North Shore Paper Company has begun preliminary construction on a development on the Manicouagan River near its mouth with initial operation of one unit planned for 1952; the ultimate capacity will be 336,000 h.p. The Labrador Mining and Exploration Company Limited is considering the development of 15,000 h.p. on the Ashuanipi River and the Quebec North Shore and Labrador Railway Company of 7,000 h.p. on the Ste. Marguerite River. Two smaller additions completed in 1950 are: 2,700 h.p. in two units in its plant on the Lievre River by the Cie Electrique de Mont Laurier; the replacement of a 500 h.p. unit by one of 1,800 h.p. by the City of Riviere du Loup. The Pembroke Electric Light Company Limited had under installation a unit of 3,000 h.p. in its Waltham plant on the Black River for operation early in 1951 and a second unit on order. The City of Sherbrooke has acquired the idle hydraulic plant of the Bromptonville Pulp and Paper Company and proposes to install generators to supplement its present electrical production. The Lower St. Lawrence Power Company is planning to develop 10,000 h.p. on the Mitis River and the City of Megantic 4,450 h.p. on the Chaudiere River. The Southern Canada Power Company and the Gatineau Power Company, while not increasing their capacity, carried out extensive additions to their transmission and distribution systems. Studies of storage and power possibilities were carried out on a number of rivers by the Quebec Streams Commission; good results also were obtained in equalising stream flow through the efficient use of its numerous storage dams.

In Nova Scotia, the Nova Scotia Power Commission in October completed its 12,800 h.p. development, in two units, on the Mersey River at Deep Brook. The Commission has recently begun construction on an 8,500 h.p. plant on the Bear River at tidewater. It also is enlarging the capacity of its steam plant at Cantley's Point by two units of 10,000 kW each, the first to come into operation early in 1951 and the second in 1952. The Nova Scotia Light and Power Company brought into operation in

September its new Paradise Brook development of 5,000 h.p. under 500 ft. head. The company is also constructing a new plant of 4,000 h.p. at White Rock on the Gaspereau River. The capacity of the company's steam plant at Halifax is being enlarged by two 20,000 kW units, one for operation in March, 1951, and the second being on order for installation in 1953. The Seaboard Power Corporation is increasing the

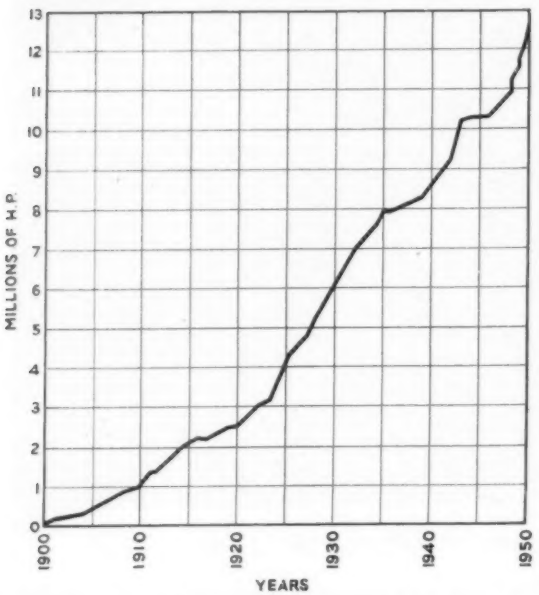


Fig. 6. Curve showing the phenomenal increase in installed capacity in Canada in millions of horse power

capacity of its steam plant at Sydney by 15,000 kW.

The New Brunswick Electric Power Commission has undertaken a development of 27,000 h.p. at "The Narrows" on the Tobique River near its mouth, with operation expected in 1953. The Commission also has under way the enlargement of the capacity of its steam plant at Grand Lake; two 6,250 kW units are expected to be brought into operation in 1951 and one unit of 15,000 kW in 1952.

In Prince Edward Island, the Maritime Electric Company at Charlottetown has under installation a new unit of 7,500 kW in its steam plant, operation being expected this year.

The Newfoundland Light and Power Company, serving principally St. John's and Bell Island, has practically completed its new development of 13,000 h.p. on the Mobile River and operation is anticipated early in 1951. It is also installing a new unit of 3,330 h.p. in its Tors Cove plant for operation this year.

Growth of Water-Power Development

Since the beginning of the present century, following the inception of long-distance transmission of electricity, water-power development in Canada has undergone a remarkable growth, the toal installation of 177,323 h.p. at the end of the year 1900 being insignificant in comparison with the 12,562,750 h.p. installed by the end of 1950. The rapid and continuous growth in installed capacity is illustrated on the diagram, Fig. 6, which shows the total installation in millions of horse-power at the end of each year, 1900 to 1950. The small vertical step at the end of 1948 shows the addition to the total for Canada of the capacity of the province of Newfoundland.

The growth in the total of hydraulic installations has been continuous and, on the whole, has tended to accelerate during the past half-century. The average annual increase in capacity of 56,000 h.p. during the first five years was sharply stepped up during subsequent years by the development of large central-electric stations, following improvement in the technique of long-distance transmission which rendered practicable the production of hydro-electric energy at sites increasingly remote from the localities of utilisation. During the period 1906-1922 inclusive, development proceeded at a fairly uniform rate of 150,000 h.p. per year. As a result of the heavier demand for electricity during the prosperous 1920's, the rate of installation increased sharply in 1923 and continued at a nearly uniform rate of 377,000 h.p. per year for the period 1923-1935 inclusive. As large-scale hydro-electric projects take considerable time to complete, there is a lag between construction and demand, the latter responding quickly to general economic conditions. When the demand for power fell off during the 1930's, projects under way were carried to completion but the result of the economic depression is reflected in the low rate of installation during the years 1936-1939 inclusive. The great demand for power for war purposes accounts for the high average rate of increase of 481,000 h.p. per year during the period 1940-1943 inclusive. Few developments were undertaken in the later war years or in the immediate post-war period, so that only a small amount of new capacity came into operation from 1944 to 1947 inclusive. However, the results of the later post-war programme of construction are apparent in the amount of growth in the years 1948, 1949 and 1950, the average rate being 603,000 h.p. per year, exclusive of the addition of the capacity of the province of Newfoundland. Present programmes of expansion indicate a continuation of this rate of growth for some years. It may be noted that in 1950, 88 per cent. of the total installation of water-power plants in Canada was of the central-station type as compared with 33 per cent. in 1900.

The photographs illustrating this article were by the Photographic Survey Corporation Limited, of Toronto.

Cambridge Index Thermometers and Thermographs. An illustrated folder received from the Cambridge Instrument Co. Ltd. gives details of their latest types of mercury-in-steel thermometers for indicating or recording at a distance temperatures up to 1,000°F.

Power Resources of Finland. It has been pointed out to us that the boundary indicated between Finland and the U.S.S.R., in the map reproduced on page 248 of the July issue, should have run north of Lake Ladoga. Certain details of this map were taken from a pre-war atlas to amplify the data given on the author's sketch map and unfortunately the old boundary was followed. This error, which we greatly regret, in no way invalidates the particulars given in the text.

North of Scotland Hydro-Electric Board Report

IN virtue to some extent of a wet year, a record generation output was obtained from the North of Scotland Hydro-Electric Board's schemes in 1950, states the annual report and statement of accounts of the Board, which has recently been published as a White Paper. Indeed, the report describes the year as "a memorable one," recalling the formal opening by the Queen of the Loch Sloy scheme on Loch Lomond last October.

The total capacity of generating plant installed in the Board's generating stations at the end of the year and the number of units generated at these stations during the year were:—

	kW Installed	kWh Generated
Water Power	284,750	521,524,062
Steam	130,875	284,374,805
Diesel (for public supply)	29,285	52,447,650
Diesel (for temporary constructional supply)	8,060	19,632,962
Total	452,970	877,979,479
Corresponding total for 1949 ...	250,970	710,194,025

The 877,964,479 kWh generated during 1950 were disposed of as follows:—

	kWh sold	Percentage difference compared with 1949
kWh sold in Board's Area ...	586,578,058	+ 14·8
kWh sold to British Electricity Authority	135,936,400	+ 141·8
kWh used in the construction of hydro-electric schemes	19,000,000	− 29·6
kWh lost in transmission and distribution	136,465,021	+ 17·9
	877,979,479	+ 23·6

The cost of coal, diesel oil and other materials increased during 1950.

No fewer than 105 villages, hamlets and housing areas were connected and the Board generated 877,979,479 units of electricity. The Board also made special efforts to give the maximum assistance to the B.E.A. system in Southern Scotland.

The Loch Sloy scheme, which was the first scheme promoted by the Board and which will have an installed capacity of 130,000 kW, was designed as a "peak load" station to give Glasgow and the West of Scotland the extra power needed in the periods of highest demand. The new power station, though its full output was not yet available, helped to meet the heavy demands for electricity during the very severe weather in November and December of 1950; the Clunie and Pitlochry stations of the Tummel-Garry scheme in Perthshire, total capacity 76,200 kW, and the Grudie Bridge station of the Fannich scheme in Ross-shire, capacity 24,000 kW, which were also in operation by the end of the year, met the rapidly growing load in the Board's area and helped also to meet the demands of the rest of Scotland.

The Board installed during 1950 hydro-electric generating plant with a total capacity of 197,950 kW and diesel generating sets with a capacity of 5,980 kW, a total of 203,930 kW. At the end of the year, the Board had in operation 13 hydro-electric, six steam and 28 diesel stations. Nine hydro-electric schemes were under construction. The Report forecasts that a start will be made soon on the construction of the following five schemes—Gaur and Lawers (Perthshire), Glascarnoch - Luichart - Torr Achilty (Ross-shire), Moriston and Garry (Inverness-shire). These schemes will have an approximate capacity of 198,200 kW and an average estimated annual output of 736,000,000 kWh of electricity. (Preliminary work is beginning at Gaur, Lawers, Luichart, Torr Achilty and Garry).

The Board had under survey last year hydro-electric schemes which it is estimated will have an approximate capacity of 278,500 kW and an estimated average annual output of 1,068,000,000 kWh. These included the Shin, Orrin, Kilmelfort and Breadalbane schemes (which have been published this year, 1951) and also proposals to use the water of the Rivers Farrar and Beauly, the Tay Basin and extensions to the Affric scheme.

By the end of 1950, the Board's programme of the development of the water power resources of the Highlands had reached the following stage:—

	Total Capacity kW	Estimated Annual Output kWh
In operation	199,700	376,000,000
Under construction	299,300	465,000,000
Promoted and just starting ...	198,200	736,000,000
Promoted	8,100	27,500,000
Under survey	278,500	1,068,000,000
	913,800	2,672,500,000

The Board promoted seven constructional schemes in 1950; one was the Mucomir hydro-electric scheme near Fort William which will have an installed capacity of 1,500 kW and an estimated annual output of 9,000,000 units of electricity; three schemes were for the construction of diesel generating stations at Kirkwall in Orkney, Lerwick in Shetland, and Stornoway on the Island of Lewis; one was for the construction of a diesel generating station and an extension to an existing small hydro-electric station at Tobermory on the island of Mull, and two were for the erection of 132,000 volt transmission lines from the Fasnakyle generating station of the Affric scheme to Fort Augustus and from Boat of Garten to Aberdeen.

The number of new consumers connected to the Board's mains during the year was 22,140, compared with 18,797 during 1949. Of the new consumers, 16,000 were in rural areas. The total number of consumers receiving a supply from the Board by the end of the year was 244,314, a figure which represents approximately 855,000 people.

From January 1, 1948, to December 31, 1950, 56,700 new consumers have been given a supply for the first time in the Board's area. There are about 120,000

(Continued on page 306)

Wind Power

In this article Percy H. Thomas of Washington, D.C. discusses various aspects of using wind power and its potentialities as a contribution of energy to a utility network system.

THE engineer studying this subject for the first time will be surprised to find that, at least when utilised as an auxiliary in a widespread utility network, the wind offers a very important source of available energy, receivable in a manner entirely acceptable to the system, and at a low cost. Unfortunately, my space is too limited to cover any but the most essential of the unique features of the aerogenerator and the natural part it plays in a power system.

Patterns of the Wind

The patterns of the wind must first be determined. At any one location, the velocity of the wind is variable and unpredictable, much more so than the flow of water in a stream or river. Continuity of supply from any one wind source can come only from energy storage.

For large-scale operations hydro reservoirs offer the only feasible means for such energy storage. The practical technique consists in setting up a value for the average annual rate of output by the aerogenerator, conveniently called its "energy capacity," which indicates the aggregate output expected from it. During periods when the generation is above this energy capacity the excess power is used by the load dispatcher to reduce the drain of water from some appropriate reservoir.When the output of the aerogenerator drops below the energy capacity, the load dispatcher calls upon this reservoir to make up the deficiency. The energy capacity being the average output, the excess and deficiency will be equal. There is this complication, that when the hydro reservoir is called upon to "pinch hit" for the wind, there must be a hydro generating unit able to use the water from that reservoir to supply the firming power. To this extent, it duplicates the capacity of the aerogenerator.

To return to the patterns of the wind. While day to day vagaries are well understood, it is not generally known that the *average* velocities of the wind have more or less definite and predictable values. The general picture of the wind is that of a vast river of air (equivalent to a stream of air of the density at the earth's surface, five miles deep), flowing generally from the arctic regions to the torrid zone, irregularly eddying from place to place and from time to time, but still, as a whole, moving along at the appropriate rate set up by Mother Nature. To study these patterns more closely, the writer examined the wind velocity records of the U.S. Weather Bureau, particularly the records of some 50 permanent recording stations covering a period of 31 years. While these stations were not at points that would be appropriate for windmills, no doubt the *patterns* observed would be followed by winds at other points, though perhaps with higher or lower average velocities.

It was found that the *annual* average of the hourly reported readings was quite uniform, varying a few per cent. up or down, but never dropping below about 85 per cent. of the long-term average. Also that the monthly average of the hourly reading never fell below one half of the annual average for that year. While no actual numerical determination was made, the indications were that the weekly averages had an important degree of stability.

Again, there was found a seasonal variation, with the monthly average values running lower in June, July, August and September, dropping occasionally as low as 85 per cent.

This outline of the patterns of the wind, as they probably exist in the U.S.A., is very helpful in appraising the probable value of wind energy for power purposes. At this point it is desirable to point out the effect of the "cube law" in relation to flowing fluids, which is to the effect that the energy content of a stream of air is proportional to the cube of its velocity. This means that the variations of the *energy* content of the wind are far wider than its velocity variations. While this seems at first sight to be a very serious obstacle to the beneficial use of wind power, it will be seen below that there are compensating conditions.

One of these is found in what is known as the energy-pattern factor. Suppose the wind blows for two hours at 20 miles an hour; the total energy passing in that time is 2×20^3 or 16,000. If, however, the wind blew for one hour at 10 miles per hour and one hour at 30 miles, the total energy would be $10^3 + 30^3 =$ 28,000, an increase of 12,000 even though the average wind velocity is the same in both cases. The ratio of 28,000 to 16,000, the energy at the average rate, is the "energy-pattern factor." It numerically equals 1·75 in this illustration. The numerical value of this factor in the natural winds depends upon the extent of the momentary variations of the wind velocity from the average. The writer, in studying forty actual cases, found extremes for this factor from 1·35 to 3.

With this picture of the behaviour of the winds, a consideration of various ways and means for bridging the low points to get steady or "firm" capacity from its energy may be taken up.

Continuous Power from Isolated Areas

First will be considered those more or less isolated locations where no electric service is attainable by the usual methods. Little specific in the way of suggestions can be offered without some definite situation to study.

By choosing a relatively low wind rating capacity with regard to the average wind velocity, it is possible to have power for an unusually large percentage of the time without firming, which reduces the amount of supporting hydro storage required. To take an imaginary case, assume a small stream with potentialities for a reservoir affording a suitable head for a

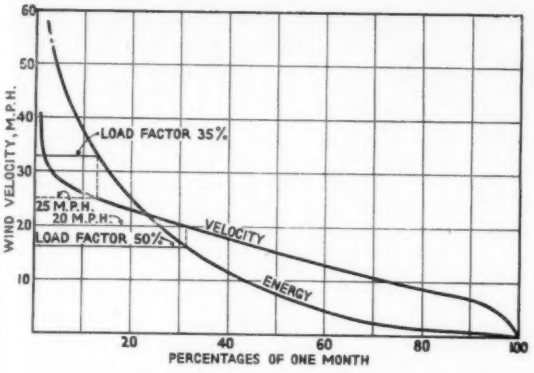


Fig. 1. Duration curves—velocity and energy

hydro plant. If then hydro generating units be installed of a capacity several times the steady capacity of the stream during the low months, and aerogenerators of an average energy capacity somewhat over half this hydro capacity, a peak load equal to the total hydro capacity could be carried on a 50 per cent. capacity load curve. Enough hydro storage would be required both to peak the stream flow, *per se*, for a week—say, roughly equal to 36 hours' output—and in addition, enough to equalise the wind for perhaps a month. This additional storage may be estimated as equal to a week's output. This totals an aggregate storage of between eight and nine days' output, for both purposes. It will be found to be a modest storage requirement. While this power would not be particularly cheap in comparison with large-scale standards, a very considerable increase of electric power would be so obtained from the wind.

Another fairly reasonable case would be found in combining a municipal water system with wind energy, where the municipal reservoir could be so situated as to be usable for hydro power. One method of combination would be to supply electric power from hydro units using the municipal water and to operate aerogenerators in parallel with the hydro. The aerogenerators would pump back at night water used for firming power in the daytime. This power would not be as cheap as in major networks, but for isolated communities would not be unduly expensive. It is said that there are two neighbouring fair sized lakes outside the city of Hamburg in Germany with a difference in elevation of 100 metres which would be an example of a situation very favourable for wind power pumping for firming the wind.

Space will not permit further discussion of various expedients to ameliorate difficult power situations in special cases.

Firming Wind Power in Large Networks

It will be useful to take up the designer's method of choosing the capacity of his aerogenerator, both the "energy capacity," the average output for a year, and the "wind rating," i.e. the wind velocity at which the generator is expected to be fully loaded.

The designer will start with a monthly duration curve of wind velocity (Fig. 1), determined from field observations. On this curve the abscissa of any point represents the portion of a month that the wind velocity is equal to, or greater than, the wind velocity represented by the ordinate of the point. From this velocity curve he constructs an *energy* duration curve in which the ordinate of any point is the cube of the ordinate of the point having the same abscissa in the velocity curve. The points on the new curve thus represent energy.

The designer then chooses arbitrarily a trial rated wind velocity for his turbine. This velocity may be taken as 25 miles per hour shown by the upper horizontal line in the figure. Then the total energy that will be developed by the turbine will be represented by the area under this horizontal line and under the part of the duration curve to the right, less of course the energy wasted when the wind is too low to use. This gives him his capacity factor. This determination is repeated for each month in the year. A second trial-rated wind is then chosen and so on until a satisfactory rating is found. It is clear that the energy under the horizontal velocity lines cannot be utilised unless some way is found to waste the portion of the energy in the wind above this line. This wasting may be done in several ways.

TABLE I

Net energy developed by aerogenerator with different wind ratings under duration curves
C.F. = Capacity Factor; Epf = Energy Pattern Factor; kWh, in millions

Rated wind Capacity	34 m.p.h.		32 m.p.h.		30 m.p.h.		28 m.p.h.		27 m.p.h.		26 m.p.h.		24 m.p.h.		No wind limit		Obs. max. wind vel.
Months	kWh	C.F.	kWh	C.F.	kWh	C.F.	kWh	C.F.	kWh	C.F.	kWh	C.F.	kWh	C.F.	kWh	Epf.	m.p.h.
Jan. -	2·05	·33	1·93	·38	1·81	·43	1·69	·48	1·62	·48	1·56	·56	1·42	·64	2·83	1·68	45
Feb. -	2·60	·45	2·34	·48	2·09	·52	1·82	·56	1·71	·56	1·60	·61	1·35	·66	4·45	1·87	47
March -	2·32	·37	2·20	·43	2·08	·49	1·93	·55	1·84	·59	1·76	·63	1·48	·69	2·61	1·44	47
April -	2·53	·42	2·32	·47	2·12	·52	1·92	·56	1·77	·59	1·67	·62	1·43	·68	2·96	1·45	46
May -	2·62	·42	2·41	·47	2·05	·52	1·97	·56	1·85	·59	1·73	·62	1·50	·68	3·88	1·67	42
June -	1·54	·25	1·49	·30	1·45	·36	1·40	·41	1·35	·41	1·28	·48	1·16	·55	1·55	1·36	35
July -	1·40	·23	1·37	·27	1·32	·31	1·25	·36	1·22	·36	1·18	·42	1·08	·50	1·46	1·40	41
August -	2·25	·36	2·08	·41	1·94	·46	1·28	·51	1·68	·51	1·60	·58	1·41	·65	2·60	1·57	47
Sept. -	1·46	·24	1·38	·28	1·30	·32	1·22	·36	1·17	·36	1·13	·42	1·01	·49	1·96	1·74	38
Oct. -	1·96	·31	1·87	·37	1·80	·43	1·70	·48	1·62	·48	1·53	·55	1·35	·62	2·32	1·48	34
Nov. -	2·41	·40	2·27	·45	2·12	·51	1·86	·59	1·76	·59	1·69	·63	1·36	·70	1·96	1·39	35
Dec. -	2·17	·35	2·03	·40	1·90	·44	1·73	·49	1·53	·49	1·54	·55	1·34	·61	2·61	1·49	36
For Year	25·30	·35	23·71	·39	22·06	·44	19·77	·48	19·13	·52	18·37	·56	15·88	·62	31·20	1·60	47

Net energy determination based on 12 monthly duration curves for the year 1940 from U.S. Weather Bureau Station at Atlantic City, New Jersey

The writer's studies indicate that capacity factors of from 40 to 60 per cent. will be natural and favourable. Table I gives the results of such a study based on a 7,500 kW aerogenerator described in the Federal Power Commission Monograph "The Wind Power Aerogenerator," issued in Washington, D.C.

The technique for firming the wind power in large utility networks, the primary object of this article, will now be taken up. The new factor in firming the wind here involved is wind diversity. When many widely spaced wind turbines are connected into the same system, it is found that the joint generation never drops to zero, but, under favourable conditions, has a very important minimum value below which generation never falls. Locations but a short distance apart often have very material diversity. At least this minimum diversified value is available 24 hours a day, so that when stored for use on the peak of the load, the energy so supplied under the diversified minimum may be used to support a much larger capacity than the minimum value itself. However, storage is required for all such firming of power, at least above the diversified minimum capacity.

To give a realistic idea of what diversity values are actually available in a widespread network, and what benefit may be secured therefrom, the writer made a study of some 12,000 hourly velocity readings for 17 stations of the U.S. Weather Bureau, scattered around the east of the Mississippi River, all for the month of November, 1941. This month was chosen as a critical month. In this study the average values of the *energy content* of the hourly wind readings were noted for various different periods of time within that month and the minimum diversified, or aggregate, values for each period noted. These are shown as a percentage of the annual energy average in Table II. Since the wind velocities in general are much lower at night than in the daytime, a distinction is made in certain of the minimum values.

These values are to be considered, not as final for all cases, but as illustrative values applicable in the eastern part of the U.S.A., and subject to confirmation by much more comprehensive research and by experience.

One very important choice must be made. What minimum period of time should be taken for these diversified values? It must be such a value that the generating system as a whole can accept the energy without difficulty regardless of how the energy is distributed through the period. The heat capacity of the many generators in the system, their flywheel effect, the flash storage in boilers and the complicated diversity of the many variables in the system, will surely integrate reasonable variations in the rate of supply over a four hour period, bearing in mind that the wind contribution is expected to be a minor

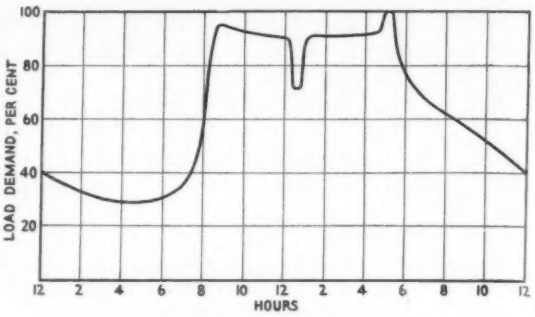


Fig. 2. Typical load-factor curve

fraction of the whole energy contained in the system.

The writer has thus taken the period of four hours as the minimum time for which diversified values need to be considered. This is an important decision, since the four hour minimum diversified energy is materially larger than the one hour value.

With these explanations a numerical example may be worked out to give concreteness to these conclusions. Assume a typical peak-load curve, chosen as a basis for studying the limiting values of wind-backed capacity. Assume a 50 per cent. load factor for the curve and that it has a 12 hour peak, with its own load factor 75 per cent. Also that this 12 hours constitutes 40 per cent. of the peak capacity; Fig. 2 illustrates such a load curve. Assume now that the sum of the various sources of firm power in the system, steam, run of river hydro which is not subject to storage, and the minimum diversified four hour wind power capacity, aggregates 60 per cent. of the peak of the curve. This leaves 40 per cent. on the peak to be covered by stored hydro energy, either from such surplus of run of river water as would be stored under a regime without wind power, or accumulated from river run in virtue of the energy supplied by the wind. The problem now is to find for how much of the 40 per cent. the wind can supply firming energy.

It will be convenient to choose a new unit to use in this example, both for energy and capacity. This unit is 1 per cent. of the peak of the load curve, as a capacity unit, or the amount of energy this 1 per cent. can generate in 24 hours, for the energy unit. Thus the total energy under the load curve will be 50 units and the peak load 100 units of capacity.

As a matter of convenience Table II has been added showing the minimum values of the diversified wind energy taken for various periods of time, and shown as percentages of the annual average of all the stations.

To solve this problem there must be a definite

TABLE II

Minimum diversified average values of hourly wind energy readings, 17 stations in U.S.A. east of the Mississippi River, expressed as percent of the annual average energy

Around the clock				Daytime only			Night
1 year	1 day	1 week	1 month	1 hour	4 hours	10 hours	1 hour
100%	40%	45%	55%	11·3%	23·8%	40%	12·7%

value set for the total chosen average energy capacity of the aerogenerators. A trial value of 22·5 units will be first considered, the peak of the load being 100 units. Using the four-hour minimum diversified value from Table II gives $22{\cdot}5 \times {\cdot}25 = 5{\cdot}6$ units for the available firm wind capacity requiring no storage. If, now, there is hydro storage enough to equalise one day of wind energy, there is available $22{\cdot}5 \times 0{\cdot}375$ units of capacity (less the $5{\cdot}6 \times 10/24$ units used as diversified firm power), left for use on the peak for supporting a part of the 40 per cent. It should be noted that the actual energy necessary to firm the whole 40 per cent. of the peak is 40 per cent. $\times 12/24 \times 0{\cdot}75$ or 15 units of energy. The number of firming energy units available from the one day minimum diversified wind energy is $22{\cdot}5 \times 0{\cdot}375 - 5{\cdot}6 \times 12/24$ or $8{\cdot}45 - 2{\cdot}8$ or 5·65 units, about one-third of the total requirements. The rest must be made up from the hydro regularly stored from stream flow (see Table III).

If now we had storage enough for equalisation of one week of wind, the energy available from wind will be $22{\cdot}5 \times 0{\cdot}45 - 2{\cdot}8$ or $10{\cdot}1 - 2{\cdot}8$ or 7·3 units. However, the average units per day required to support the 40 per cent. on the peak is somewhat less than for one day (week day) on account of Saturday and Sunday. The whole week figure may be taken as 6/7 of the week day figure, $15 \times 6/7 = 12{\cdot}9$, $12{\cdot}9 - 7{\cdot}3 = 5{\cdot}6$ units required from the hydro obtained from stream flow.

Finally, assuming a month's storage for the wind the energy available for supporting the peak is $22{\cdot}5 \times 0{\cdot}55 - 2{\cdot}8$ or $12{\cdot}5 - 2{\cdot}8$, *i.e.* 9·7. This leaves $12{\cdot}9 - 9{\cdot}7 = 3{\cdot}2$ units of energy to be supplied by hydro storage from stream flow. This is as large a percentage of wind energy as would seem appropriate for this particular load curve.

By installing a larger capacity of aerogenerators than the 22·5 units, larger amounts of firming energy will be gotten from the wind. A 25 per cent. increase would be sufficient to supply energy for the full 40 per cent. of the peak from the wind, so long as sufficient storage was present to equalise a month's wind; then, $22{\cdot}5 \times 1{\cdot}25$ is 28·2 units.

Equalising a month's storage is by no means the same as storing a month's energy, for the varying wind will be putting in and withdrawing energy every few days. The capacity to store a week's output would seem adequate to equalise a month's flow.

Now any remaining energy, not used to support the peak stored from wind or hydro, will be steam replacement. The amount of steam replacement or "if and when" wind energy remaining after the minimum diversified wind energy has been assigned to peak firming can be determined as follows: The amount assigned to the peak in the case of one week's storage was 10·1 units. Since the total was 22·5 units, the "if and when" wind energy for this case is $22{\cdot}5 - 10{\cdot}1 = 12{\cdot}4$ units. From this, however, must be subtracted the small amount of firm wind capacity.

Of course, the hydro stored from stream flow might have been assigned to firming the 40 per cent. of the peak in place of the wind energy, in which case the major residual energy would be wind energy and applied as steam replacement. It makes no difference in the operation in which way it is considered. This choice, however, complicates the calculation of the numerical value of the wind power.

Choosing a different value for the wind capacity energy to be installed will change all these figures, so giving a wide range for the designer's skill. If the designer chooses a 50 per cent. capacity factor for his aerogenerators the *wind rating* total will be 22·5/0·50 or 45·0 units. If he chooses 60 per cent. it will be 22·5/0·60 or 37·5 units.

Comments on Aerogenerators

A word will be said about the control of the operations of the aerogenerator and the necessary safeties for emergencies. The first well known hurdle is that of getting a constant-frequency power from the naturally varying wind velocity. The scheme recommended by the writer is to drive a d.c. generator from the turbine through step-up gears, making the speed proportional to the actual wind velocity. The direct current is then fed to an inverted rotary converter, which runs in synchronism with the utility system. The necessary wide range of control of the direct current voltage is obtained partly by an extra control in the generator field and partly by taps in the step-up transformer.

An automatic wattmeter-type relay with two opposed coils, one energized from the wind velocity and the other by the wheel speed, will serve to keep the proper ratio of wind velocity to blade speed by raising or lowering the field strength of the generator as the relay swings one way or the other. Obviously, an increase in the field strength will increase the demand on the wind, and will slow it down, since the wind has a definite energy content at any given velocity. When an increasing wind velocity reaches the point where the generator is overloaded, a second overload relay takes command and continuously raises the field strength until the overload slows down the wheel sufficiently so that the resulting aerodynamic losses reduce the output.

To prevent runaway speed when the wheel is disconnected from the utility circuit, or in any other emergency, heavy brakes are installed on the back

TABLE IIIa

Various capacity quantities in arbitrary units — Layout from Fig. 2; data from Table II

System aerogenerators			Load curve quantities		Capacity from minimum 4-hour values, diversified—Table II
Energy capac.	Maximum wind rating				
	For capacity	Factor	Overall	Part supplied	Taken as 23·8% of annual aver. wind gen.
Average	50%	60%	load peak	from storage	
22·5	45	37·5	100	40	5·4

TABLE IIIb

Various energy quantities in arbitrary units. Layout from Fig. 2; data from Table II

Daily minimum diversified averages for aerogenerators							Load requirements for 24 hours 40% of peak load		
Around the clock				Daytime only					
Annual aver.	1 day	1 week	1 month	1 hour	4 hours	10 hours		1 weekday	1 week
22·5	9·0	10·2	12·4	2·5	5·3	9·0	50	15	13

Wind energy necessary to give minimum diversified 4-hour capacity on peak included above

of both wind wheels. These have an automatic feature and are operated alternatively by electric current, compressed air, or manually. Other safety measures should be installed in accordance with the conditions.

The very high tower proposed in the study-design has no doubt raised questions in the minds of engineers. The reasons are quickly given.

The construction cost of the aerogenerator puts a heavy premium on adequate wind velocities, which should average at least 17·5 to 22 miles per hour to secure the lowest cost power.

Over free-ground the energy content of the wind at elevation of 500 ft. is believed to be between 2·5 and 3 times that near the ground.

The wind wheel, if of the high-speed type, taps a cylinder of air several times the diameter of the wheel so that a corresponding clearance from the ground is desirable.

Only the component of the wind normal to the plane of the wheel is useful. The wind near the ground and around all rough hills or broken ground is far from being streamlined.

The cost of the 475 ft. tower of the study design is estimated as less than 25 per cent. of the whole aerogenerator.

Of course, it is not strictly necessary to have so high a tower, if this height is considered objectionable.

A word of caution; the writer has searched the literature for helpful information as to how to design a wheel to secure maximum effectiveness. No clear exposition of the subject has been found. As a matter of fact, most of what is available is applicable strictly only to the type of wind wheel in which the surface of the wheel circle is largely covered by the blades, so as to give a more or less constant flow of air throughout the wheel section; that is the farmer's type.

It appears, however, from the example of the aeroplane propeller and elsewhere, that the open type turbine wheel, with a solidity ratio of less than 10 per cent. near the tip, is far more effective, when operating with tip speeds at least half the speed of sound, than those types discussed in the literature. To make the necessary information available to engineers in a usable form, the writer has prepared a monograph "Aerodynamics of the Wind Turbine," issued by the Federal Power Commission of the U.S.A., Washington, D.C., which treats this subject for the designers of wind turbines.

Space will not permit pursuing this very important and highly interesting analysis further.

Continued from page 301

consumers or about 400,000 people still without a supply of electricity. In three years, therefore, nearly 30 per cent. of the potential consumers in the Board's area have been a given a supply.

During the year, 12,082 consumers were changed over from direct current to alternating current supply. Supplies of electricity were provided for the first time in 105 villages, hamlets and new housing areas. The total length of distribution lines at the end of the year was 5,808 miles, about 310 miles of which were erected during 1950.

The 132,000 V. Highland grid system in operation or under construction at the end of 1950 consisted of 1,120 miles of lines and 10 switching stations. The Board have promoted 10 schemes for main transmission.

The report claims that the Board by making use of local stone as far as possible in the building of generating stations, substations and staff houses, have contributed to a revival of the Scottish stone quarry industry in the north and the craft of the stonemason. For example, the new diesel generating station at Kirkwall, which will be one of the largest diesel stations in Britain, has been built of local stone as is the small hydro-electric station at Gairloch. Another application of local stone to present-day building was the facing of the Sloy, Clunie and Pitlochry generating stations with pre-cast slabs of granite from Aberdeen. The Board are building all their main groups of staff houses of stone: at Tarbet, Loch Lomondside, for the staff of the Loch Sloy scheme, at two sites at Pitlochry for the staff of the Tummel Valley stations, and at Cannich, Strathglass, for the staff of the Affric scheme.

Research work undertaken by the Board last year included an investigation into new methods of tunnel driving, experiments with an electrical fish screen and an electric enumerator to count fish passing up the fish passes at dams, research work in connection with a peat-fired gas turbine and the drying of hay by electricity. The foundations and steel tower of the 100 kilowatt experimental windmill were erected on Costa Hill, Orkney, and the machinery after being tested in the manufacturers' works, was shipped to Orkney in preparation for installation.

Capital expenditure during 1950 was £12,213,551. The profit for the year of £5,204 has been added to the balance of £22,470 brought forward from 1949 and the aggregate surplus of £27,674 is being carried forward.

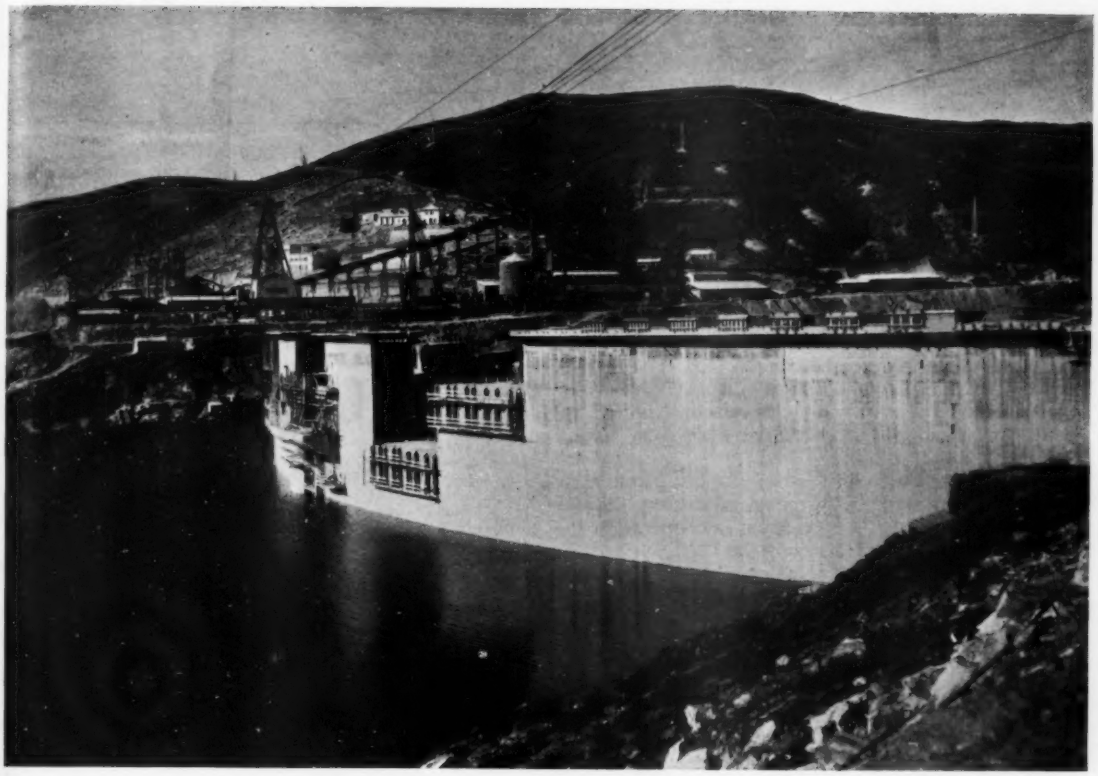


Fig. 1. Vila Nova; upstream view of dam

The Vila Nova Scheme

The second stage in an important scheme for the development of hydro-electric power in Portugal was reached on Saturday, 9th June, 1951, when the first of three water turbine generating sets was put into commission in the newly built power station at Vila Nova, about 60 miles north-east of Oporto.

THIS project had its origins in a decision taken by the Portuguese Government in 1945 to sponsor the exploitation of the country's natural resources as fully as possible. Vila Nova is situated on the banks of the Cavado river near its confluence with the River Rabagão and the scheme for the development of the Cavado-Rabagão basin was entrusted to the Hidro Electrica do Cavado, a company formed for the purpose.

The commissioning ceremony was carried out by the Senior Minister, His Excellency Dr. Costa Leite Lumbrales, supported by the Minister of Public Works and the Minister of Economy, in the presence of a large number of distinguished guests and Government and other officials. The station is being equipped, in the first instance, with three 39,000 h.p. water turbines of the horizontal-shaft double-runner Pelton type each coupled to a 32,000 kVA generator running at 428 revolutions per minute. There are also three 30,000 kVA 11/165 kV three-phase banks of single phase transformers and 165 kV and 30 kV switchgear including air-blast circuit breakers. The hydraulic and electrical equipment installed has been supplied by the English Electric Export & Trading Company and Metropolitan-Vickers Electrical Export Company who have become known in Portugal as the British Group. Room has been left in the power station for a fourth set to be installed at a later date when the demand for electrical power in Portugal has been sufficiently developed.

The water for the power station at Vila Nova is derived from a tributary of the Cavado river, the River Rabagão which flows at this point some two miles to the south-east at an altitude approximately 1,500 ft. higher. A dam about 300 ft. high has been built across the River Rabagão and is known as the Venda Nova Dam. The water from the reservoir flows first through a tunnel driven through the mountain for a distance of about 1½ miles to a valve house situated at the top of a steep declivity which runs down to the Cavado river on the banks of which the power station has been built. At the valve house the water enters a steel pipeline, which has been erected on the face of the hillside, and is led into the power

station from which, after passing through the water turbines, it finds its way into the Cavado river. This steel pipeline, eight feet in diameter and about 950 ft. long, was supplied and erected by the South Durham Steel & Iron Company acting as sub-contractors to the British Group.

The exploitation of these two rivers, the courses of which provide a natural head of nearly 1,300 ft., has called for considerable engineering ingenuity and the success of the scheme will be a lasting monument to the foresight and skill of all who have taken part in it. Placed as it is in a mountainous region full of geological faults, the site is both difficult of access and difficult to develop and the transport of the plant from the coast has not been the least of the many problems which have had to be tackled. The formation of the reservoir and the consequent flooding of part of the Rabagão valley have necessitated the complete submerging of a village known as Venda Nova.

It will be recalled that one of the last public acts of the late Marshall Carmona, President of the Portuguese Republic, was to bring into operation the power station on the Zezere river at Castelo do Bode situated about 90 miles north-east of Lisbon. This station was the first stage in the scheme for the hydro-electric development of Portugal previously referred to. The hydraulic and electrical equipment installed in this station has also been supplied by the English Electric Export & Trading Company and Metropolitan-Vickers Electrical Export Company and it is meeting the increased national demand for electrical energy without difficulty.

Fig. 2. Interior of machine hall showing first set completed and second in course of erection

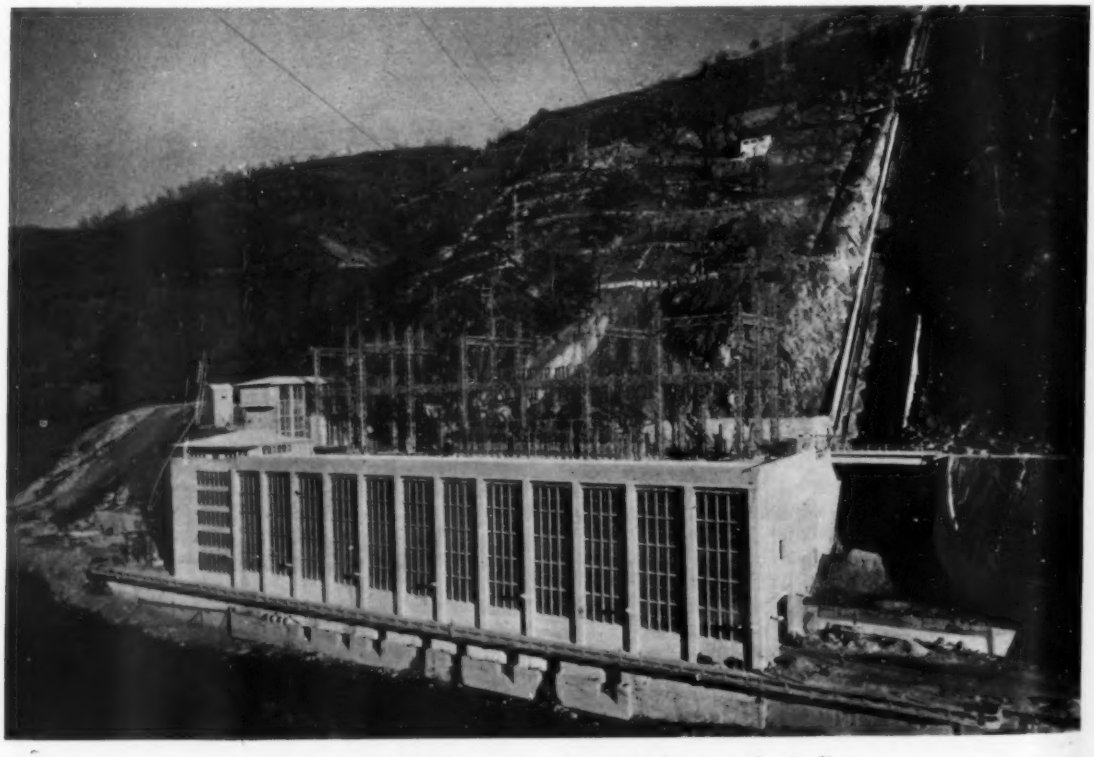


Fig. 3. General view of station, switchgear and pipelines

Physical Properties and Drillability of Mine Rocks

PART THREE. In the preceding articles, R. Shepherd, B.Sc. (Hons.) A.M.I.Min.E., F.G.S., has indicated where existing methods of rock testing are deficient when used to determine the drillability of different rocks. He now continues with discussions on the effects of bit diameter, worn bits, and measurement of penetration speeds.

SINCE the K values as already indicated vary with the diameter of bit used, there can be no standard measure of drillability based on the K value without taking into account the bit diameter. Bits also increase in weight as their diameters increase, and so the equivalent loadings with larger bits will be somewhat greater than with smaller bits.

Thus, for a certain size of bit the equivalent applied load will be $W + w$, where W is the actual applied load and w the weight of the bit.

The equivalent applied load per sq. in. of bit circle swept out will therefore be

$$\frac{4(W + w)}{\pi d^2} \text{ lb. per sq. in. where } d = \text{the}$$

bit diameter and this can be simplified to $\frac{4W_1}{\pi d^2}$ where W_1 = applied load + bit weight.

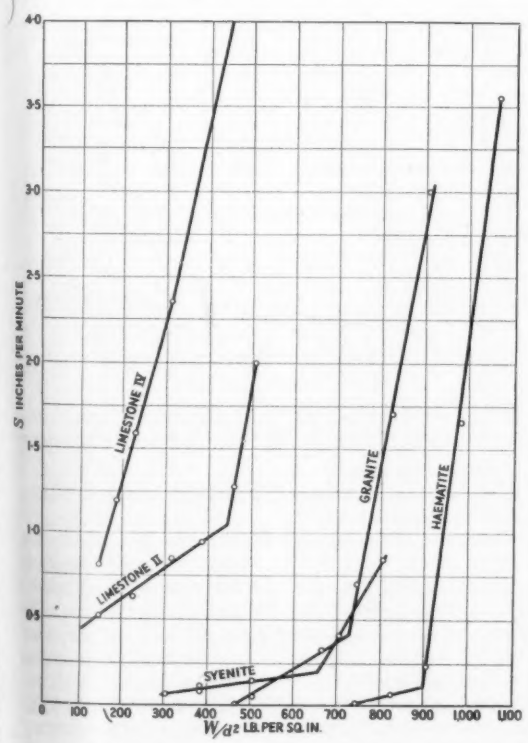


Fig. 14. Relationship between penetration speed and the ratio applied load to the square of the bit diameter

It has already been shown that

$$S = KW + C$$

where K = slope of the line and is $\frac{ds}{dw}$

Taking into account the weight of the bit and applied load per sq. in., we have

$$S = \frac{K_1 4W}{d^2} + C$$

and this gives a relationship between S and $\frac{W}{d^2}$

The slope of the line will now be $\frac{ds}{d\left(\frac{w}{d^2}\right)}$ and can be termed the K_1 value.

By carefully conducted tests the K_1 value was found to be approximately the same for all sizes of bit. This value will be more indicative of overall drilling conditions and comparative values can be obtained for different rocks using bit sizes to suit the conditions.

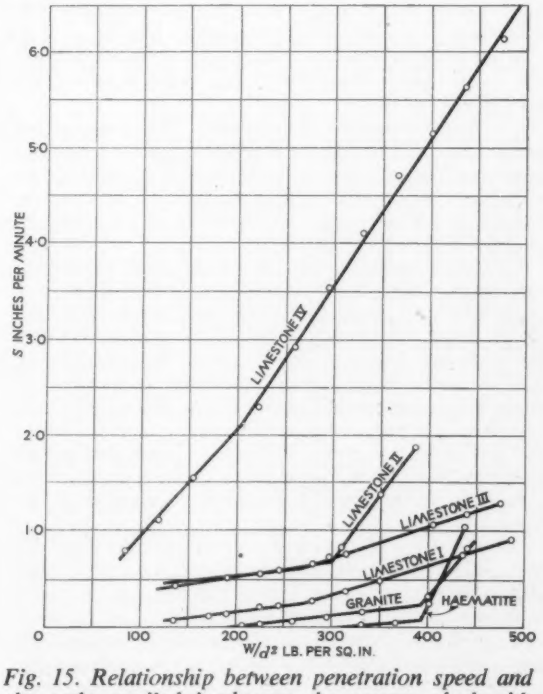


Fig. 15. Relationship between penetration speed and the ratio applied load over the square of the bit diameter

It was decided to call the upper gradient value, i.e., above the critical point, K_1, and the lower value below the critical point K_2. It was possible, by utilising the $S/\frac{W}{d^2}$ relationship to widen the scope of the tests, the small bits, $\frac{1}{2}$ in. and $\frac{3}{4}$ in., being used for the more difficult subjects and the larger bits for the softer rocks in order to obtain measurable penetration speeds. As the weight of the machine is a constant, 40 lb., it has been neglected in all cases and the value W represents the loading in excess of the machine weight.

TABLE VI.—K_1 AND K_2 VALUES

	Heavier Loading K_1 ($\times 10^3$)	Lighter Loading K_2 ($\times 10^3$)
Ironstone	153·9	73·7
Gritstone	141·5	44·8
Coal (perpendicular to cleat) ...	122·2	17·8
Coal (parallel to cleat)	65·4	17·1
Bind	62·7	19·1
Sandstone (Parkgate Rock) ...	58·1	22·3
Haematite	20·7	0·7
Limestone IV	14·1	11·0
Limestone II	14·0	1·7
Granite	13·0	1·4
Syenite	4·3	0·4
Limestone III	3·3	1·1
Limestone I	2·8	1·1

Table VI gives values for K_1 and K_2, these being obtained from the graphs S and $\frac{W}{d^2}$ for the different rocks under test. Figs. 14, 15, 16, 17 and 18 show the relationships for $\frac{1}{2}$ in., $\frac{3}{4}$ in., 1 in., $1\frac{1}{4}$ in. and $1\frac{1}{2}$ in. bits respectively. The values in Table VI are the "arithmetic means" of the measured values.

K_1 and K_2 values are studied under two headings: (*a*) light load conditions, and (*b*) heavy load conditions.

(*a*) *Light loading* (K_2 *values*). — Coarse-grained sandstone, gritstone and the green oxidised ironstone appear to respond easily to changes in loading, as to a lesser degree does the finer-grained limestones. Syenite has a very low K_2 value while haematite is slightly higher in the scale.

Gritstone has been noted as a very abrasive subject, but, on the other hand, is loosely grained. The combination of these two factors determine the K_2 value, which in this case is 44·8. The maximum critical value for gritstone for new bits up to $1\frac{1}{2}$ in. diameter is 100 lb. and, as has been already stated, this comparatively low reading will cause a fair degree of bit wear. Decreasing the load will increase the wear and a rapid fall in penetration speed will result. Ironstone, on the other hand, as tested, is not abrasive, but the peculiar structure of the actual sample will result in high K_2 values.

(*b*) *High loading* (K_1 *values*).—The table gives the K_1 values in descending numerical order. Ironstone and gritstone are again high in the list, but the coal-measure sandstone (Parkgate Rock) is not so prominent. Some rocks, such as haematite and syenite, while difficult to drill at low loading values, appear to be more susceptible to increases in load under high loading conditions, and compare favourably to some

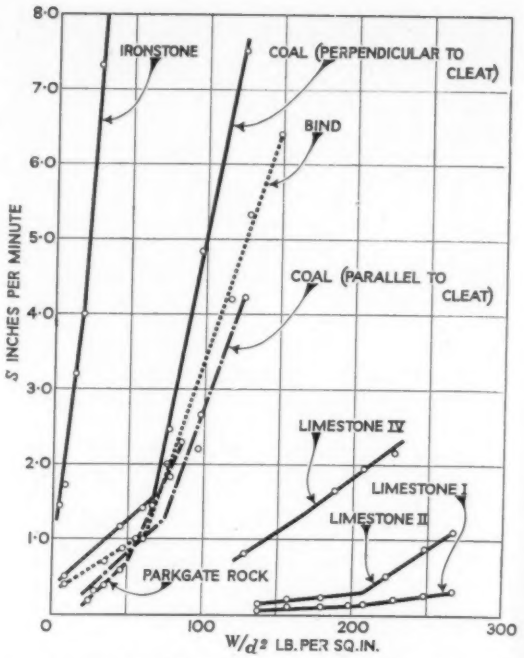


Fig. 16. Relationship between penetration speed and the ratio applied load over the square of the bit diameter

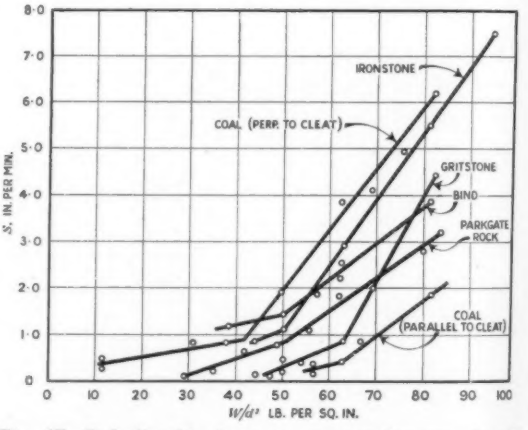


Fig. 17. Relationship between penetration speed and the ratio applied load to the square of the bit diameter

limestones, e.g., limestones I and III, which are alike in some respects.

Abrasion appears to influence the K_1 value to a smaller extent than the K_2 value. The coal sample is not particularly abrasive yet decrease in load results in a fairly rapid fall in penetration speed, especially when the subject is drilled perpendicular to the cleat.

It is essential to bear in mind that abrasion alone does not influence the K_1 and K_2 values. A particular physical property or variable influences the drillability of a subject when that variable has a preponderance over the remaining variables.

Present state of knowledge of the subject indicates

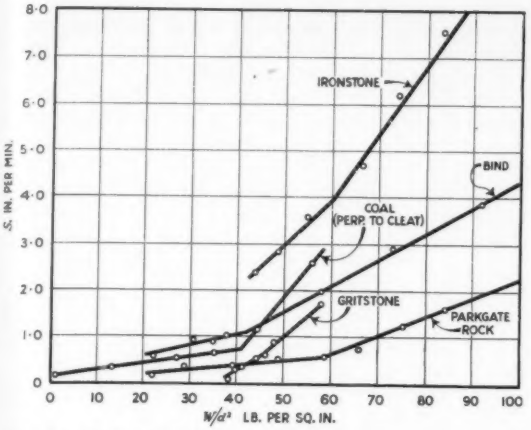


Fig. 18. Relationship between penetration speed and the ratio applied load to the square of the bit diameter

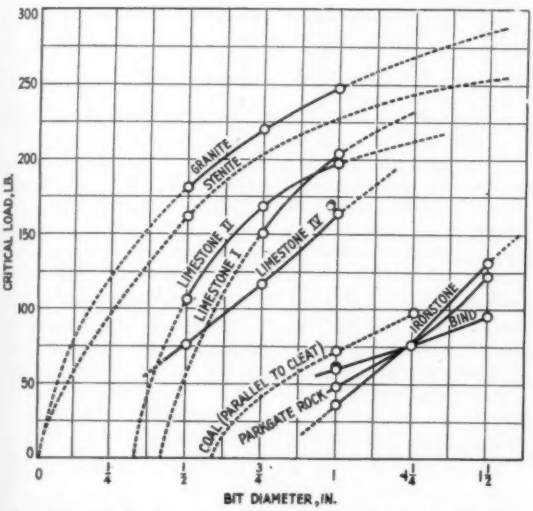


Fig. 19. Variation in critical load for varying sizes of bit

that the following variables influence (*a*) the K_1 and K_2 values, and (*b*) the critical value.

1. Abrasiveness of the rock.
2. Size of grains or minerals.
3. Shape of grains or minerals.
4. The nature of the matrix.
5. The toughness of the rock.

It appears to be reasonable to assume that the K_1 and K_2 values are influenced therefore by the algebraic summation of the above variables and give values which indicate the overall drillability of a particular subject.

Before we can estimate the individual extent to which each independent variable influences the overall values obtained, it is necessary to analyse the petrological composition of each subject.

For an accurate evaluation of K_1 and K_2 in each case it was necessary to perform very careful tests, particularly in abrasive rocks. In all cases the bit, if it showed signs of wear denoted by loss in weight, was reground before re-use in either the same rock

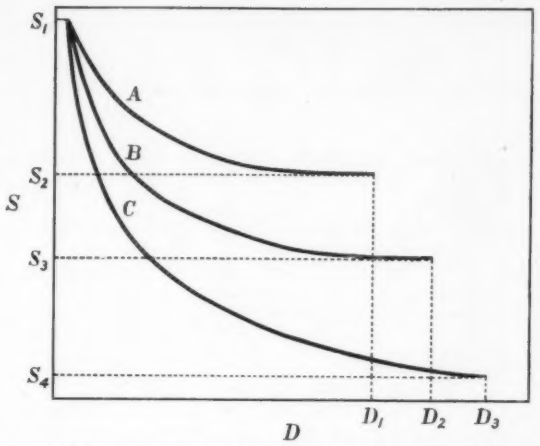


Fig. 20. Graphs illustrating the hypothetical relationship between penetration speed S and depth D for three rock samples, drilled by the same diameter bit, and under constant load conditions

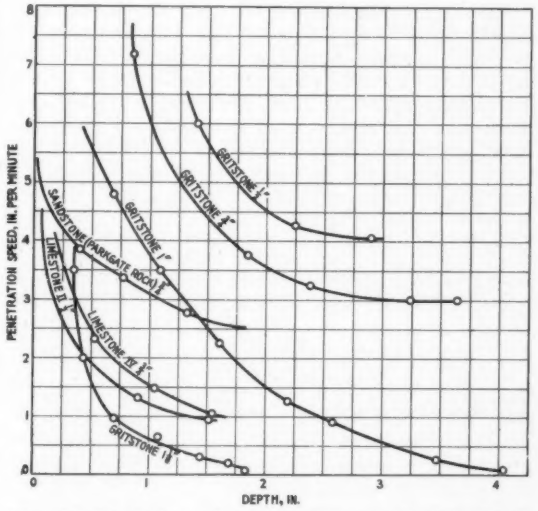


Fig. 21. Variation of penetration speed with depth, under constant load

or other rocks. Thus, by careful weighing after each run it was possible to determine how the standard conditions had varied. The total gauge loss for each bit taken over the full period of testing amounted to less than 0·001 in., and so can safely be ignored.

Critical load

The rate of variation of critical load for varying bit diameters is shown in Fig. 19, while Table VII lists the values in terms of $\frac{W}{d^2}$ units and in lb. The curves shown in full lines indicate that there is a progressive increase in the critical load for increases in bit diameter, but it is difficult to lay down any hard and fast rule for the increase, i.e., there is no law applicable to all rocks. Curves for some rocks, e.g., syenite, haematite, etc., have critical loads for all bit sizes, and it is fairly correct to assume that rocks

TABLE VII.—CRITICAL LOADS FOR VARIOUS BIT SIZES

	$\frac{W}{d^2}$ lb. per sq. in.					W lb.				
	½ in.	¾ in.	1 in.	1¼ in.	1½ in.	½ in.	¾ in.	1 in.	1¼ in.	1½ in.
Granite	728	392	248·5	(174·5)	(128·3)	181·5	220	247	(270)	(285)
Syenite	567	(367)	(228·5)	(157·2)	(115)	163·75	(205)	(227)	(243)	(255)
Haematite	901	392	—	—	—	220	225	—	—	—
Limestone I	—	267	205	(149·5)	(112·6)	(60)	150	203·5	(231)	(250)
„ II	445	298	197	(136·6)	(90·5)	106	167·5	195·5	(211)	(220)
„ III	—	267	—	—	—	—	150	—	—	—
„ IV	305	203	167·5	(136·1)	(115)	75·75	114	166	(210)	(255)
Gritstone	—	—	—	63·0	45·5	—	—	—	96	99
Sandstone (Parkgate Rock)	(102)	(58·6)	50·0	50·5	57·6	(25)	(32)	48·5	76	123
Bind	(100)	(80·0)	62·0	50·0	42·5	(27)	(44)	60·5	75·9	95·6
Ironstone	(4·0)*	(1·78)*	37·5	50·1	59·7	(Zero)	(Zero)	36	76	131
Coal (I to cleat)	—	—	65·0	42·0	41·3	—	—	63·5	63·9	89·4
„ (II „)	(4·0)*	(72·8)	72·5	62·5	(53·5)	(Zero)	(40)	71	95·8	(117)

*Due to weight of drill only.
( ) Interpolated values.

which exhibit gradient changes on the $S/\frac{W}{d^2}$ curves for all bit sizes comprise the more difficult rocks so far as drillability is concerned.

Assumed extensions of the curves are shown in broken lines. Only limestone IV, bind and possibly ironstone conform to straight-line relationships within the limits of the test. Most limestones appear to have low critical values for small bit diameters, while coal is drilled at the higher value K_1 for bit diameters less than ½ in. The actual example of ironstone used in these investigations exhibits no gradient change for bits smaller than 1 in. dia.

TABLE VIII.—COMPARISON BETWEEN REGROUND AND WORN BITS

Subject	Bit Size	Critical Load lb.
Coal (perp. to cleat) ...	1 in. (Reground)	63·5
„ „ „ ...	¾ in. (Worn)	101·0
Sandstone (Parkgate Rock)	1 in. (Reground)	48·5
„ „ „	1¼ in. „	76·0
„ „ „	¾ in. (Worn)	96·0
„ „ „	1¼ in. „	96·0

TABLE IX

Subject	K_1	K_2	Bit Condition
Coal (perp. to cleat) ...	125·0	17·57	Worn. ¾ in.
„ „ „ ...	122·2	17·80	Reground bits (see Table VI)
	61·0		
Sandstone (Parkgate Rock)	57·4	—	Worn ¾ in.
„ „ „		23·3	Worn 1¼ in.
„ „ „	58·1	22·3	Reground bits (see Table VI)

Effect of using worn bits

Bits of the sizes ¾ in., 1¼ in. and 1½ in. which had become dulled were tested in the coal and sandstone samples, i.e., in a non-abrasive and in an abrasive subject. The present coal sample is classed as a non-abrasive subject since it contains no abrasive bands such as of pyrites, etc.

The effect on (*a*) critical load and (*b*) K_1 and K_2 values were studied.

(*a*) *Critical load.*—Table VIII gives the values for critical load.

The noticeable effect produced by drilling with worn bits is the requirement of a heavier loading to produce a change in the gradient of the $S/\frac{W}{d^2}$ curves.

(*b*) K_1 *and* K_2 *values.*—Table IX shows the K_1 and K_2 values for certain new and reground bits.

Although the penetration speed is much lower, as is well known, when using worn bits and a greater load is required to effect a more rapid increase in penetration speed, the K_1 and K_2 values for worn and reground bits as shown in Table IX are approximately the same.

From this it may be inferred that worn bits may be used for determining the drillability of a particular rock providing the degree of wear is not such as to reduce the penetration speeds to very small immeasurable values.

Penetration speeds

One method often used for the determination of penetration speed is to drill a fixed depth under a constant load or thrust. This method is suitable for comparing bits, machine performances, etc., providing all tests are carried out in the same rock, but is not suitable for comparing rock drillabilities where the rocks have diverse abrasion characteristics, grain size, etc.

Fig. 20 illustrates the hypothetical relationship between penetration speed S and depth D for three rock samples, A, B and C, drilled by the same-diameter bit, and in each case under equal constant load conditions.

Assume that all rocks have the same initial penetration speed S, but that C is a very abrasive rock, B less abrasive and A least abrasive.

Since A is least abrasive the rate of fall in penetration speed will be the least followed by B, and C will have the greatest rate of fall. Rock A will achieve its approximately constant or asymptotic value S_2 at depth D_1, but B will not achieve its approximately constant value S_3 until depth D_2 has been drilled and C its approximately constant value S_4 at D_3. In order to reduce the rate of fall to the value given by A, it would be necessary to increase the load in each case. Even the least abrasive rock displays this initial fall

in penetration speed under constant loading, and it may be attributed not only to abrasive properties, but also to increasing rock resistance. If short drill runs are not made over the depths D_1, D_2 and D_3 the effect of build-up of cuttings exerting a resistance must also be considered as another factor.

Thus, the average penetration speed is the area bounded by the curve, the S axis and the asymptote divided by the total depth drilled before the asymptotic value is reached.

In the case of rock A this will be:—

$$\frac{\int_0^{D_1} \frac{R_1}{D^{n_1}}\, dD}{D_1}$$

$$\frac{\int_0^{D_2} \frac{k_2}{D^{n_2}}\, dD}{D_2} \qquad \text{for rock B}$$

and

$$\frac{\int_0^{D_3} \frac{k_3}{D^{n_3}}\, dD}{D_3} \qquad \text{for rock C}$$

assuming that the graphs connecting S and D are rectangular hyperbola with respective constants k_1, k_2 and k_3.

Thus, the calculated average penetration speed is dependent on the depth drilled and a wholly inaccurate estimation may be made if drilling be stopped short of the point where the asymptotic value is acquired or carried further, unless the values are plotted and the required values obtained from the resultant graphs.

Fig. 21 illustrates the results obtained under constant loading conditions. It will be seen that low abrasive rocks such as limestone II and IV (non-siliceous) and ironstone have lower rates of fall in penetration speed than, say, gritstone and sandstone, which are more abrasive. The bit diameter will, of course, influence the S/D curves as the rate of bit abrasion is not the same for two bits of unequal diameter.

The penetration speeds were measured for each rock subject over a very short depth of hole with constant load, and the graph, Fig. 22, shows the relationship between the penetration speed and the square of the bit diameter with a constant loading 126 lb. This load was selected for the test since it represented the maximum load possible with the machine before it was modified to take heavier loadings. The values of the penetration speeds recorded on the graph comprise:—

(*a*) Initial values obtained at the commencement of routine tests with 126 lb. loading.

(*b*) Values obtained on non-abrasive rocks for intermediate loadings of 126 lb., where initial loadings were much higher.

(*c*) Average results from special tests with 126 lb. loading.

It is aparent from the curves that S is proportional to $\frac{1}{d^2}$. This is verified in Fig. 23, which shows the straight-line laws connecting S and $\frac{1}{d^2}$

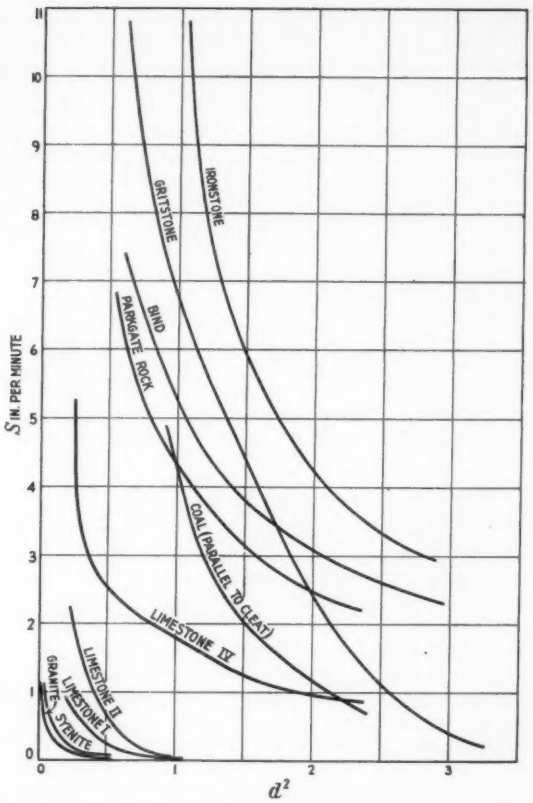


Fig. 22. Variation in penetration speed relative to the square of bit diameter under a constant load of 126 lb.

Fig. 22 indicates that very small bit diameters give infinitely high penetration speeds. Likewise very large bits will result in infinitely low speeds, although zero penetration speed will not be acquired with any large bit providing it still rotates. In practice, infinitely small bits under heavy load, of course, would not achieve any penetration, owing to the flexing of the necessarily small-diameter drill steel.

The exact relationships already discussed are true only for the special solid test bits used, but there is no reason to dispute that similar graphs would be obtained for other type bits providing:—

(*a*) The load was kept constant.

(*b*) The rotary speed (r.p.m.) was constant.

(*c*) Each bit had equal cutting angles, equal clearance angles and the same design.

(*d*) The correct technique of observing the penetration speed was adopted as discussed.

Penetration speed under constant load conditions

It has been shown already that for any single bit $S \propto W$, S being the penetration speed and W the applied load. For all bit sizes $S \propto \frac{W}{d^2}$ where d is the bit diameter. If l is the height of the cutting edge and t secs. the time which elapses before l has been drilled, i.e., before the cutting edge has been totally immersed in the rock and the full bit diameter utilised.

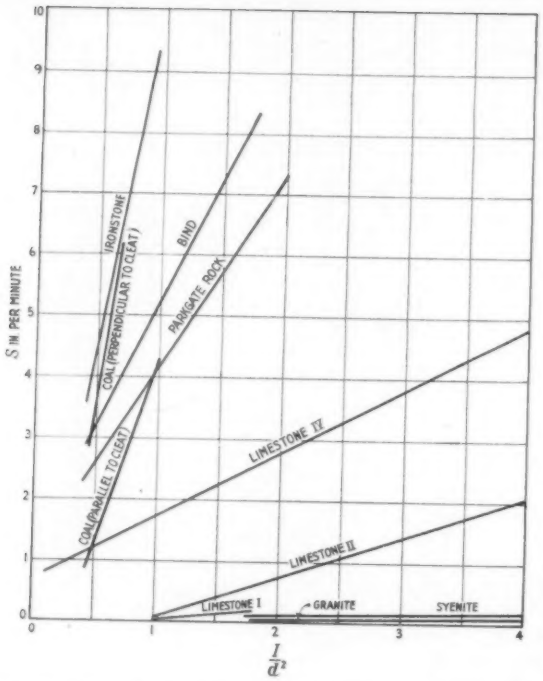


Fig. 23. Variation in penetration speed to the reciprocal of bit-diameter squared, under constant load conditions

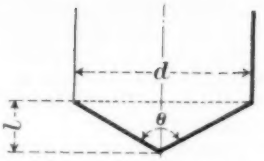


Fig. 24. The dimensions of a drilling bit

When depth drilled is less than l:—

$$S \propto \frac{W}{d_1^2} \quad \text{where } d_1 < d$$

$$\text{i.e., } S \propto \frac{1}{d_1^2}$$

If θ be the cutting angle, see Fig. 24,

$$\text{then} \qquad \frac{d}{2} = l \tan \frac{\theta}{2}$$

$$d^2 = 4\, l^2 \tan^2 \frac{\theta}{2}$$

$$\text{but} \qquad S \propto \frac{1}{d^2} \text{ as already indicated;}$$

$$\text{therefore} \qquad S \quad \frac{1}{l^2}$$

therefore over the depth l, S against l^2 is a rectangular hyperbola.

After the full depth l has been drilled, assuming constant load conditions, the fall in S will depend on several conditions: (1) extent of abrasive wear of the cutting bit; (2) the changing conditions of the rock, i.e., whether or not the bit has passed the weathered crust zone.

(To be continued)

H. A. Sieveking

It is with regret that we have to record the sudden death of Mr. H. A. Sieveking, M.Sc.(Eng.), M.Inst.C.E., M.I.E.E., of The English Electric Company, who died, at the age of 46, on June 20th last. He was a distinguished hydro-electric engineer, and in addition to contributing to *Water Power* on a number of occasions, he was always ready to give advice and assistance to the editorial staff from his world-wide experience in the field covered by this journal.

Apprenticed with the British Thomson-Houston Co. Ltd., he entered their Switchgear Department in 1928, but subsequently left them to study hydro-electric practice with J. M. Voith, in Germany. He served with the Central Electricity Board, in London, from 1933 to 1940, during which time his work covered a diversity of matters, such as comparisons between public supply and private generation for large loads. From 1940 to 1945, he was with James Howden & Co., as chief electrical engineer and technical assistant to the board of directors, and in the latter year he joined the Hydro-Electric Department of the English Electric Co., being largely concerned with projects in Canada, Brazil and India. He also lectured on hydraulic turbine design at the Imperial College of Science and Technology, and earlier this year gave a series of lectures at King's College, London, on "Some Aspects of the Development of Hydro-Electric Power." He was also a barrister at law, having been called to the Bar at the Middle Temple in November, 1938.

In Parliament

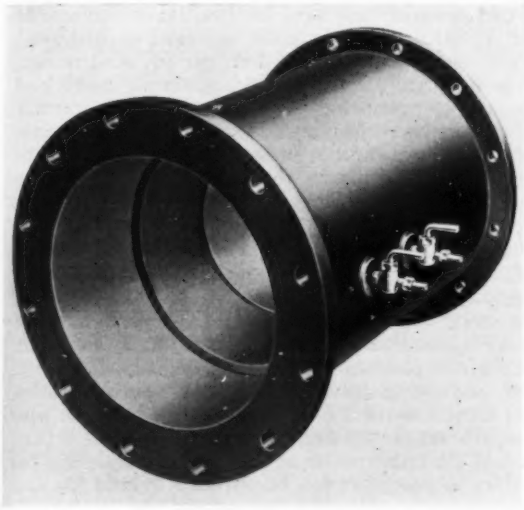
In the House of Commons on July 2 Colonel Gomme-Duncan asked the Secretary of State for Scotland what was the original estimated cost of the Loch Sloy, Loch Morar and Lochalsh hydro-electric projects, what, to date, was the actual expenditure, and what was the latest estimate for the completion of these projects. Mr. McNeil said the estimated cost in 1944 of the three projects mentioned was £4,600,000. He was informed that the expenditure on these projects to the end of May 1951 was £9,043,000.

Colonel Ralph Clarke asked the Minister of Fuel and Power what experiments were being undertaken with a view to the development of small and medium-sized hydro-electric projects. Mr. Noel-Baker said the British Electricity Authority had under consideration a number of hydro-electric projects of small and medium size, and investigations were proceeding to see whether they would be economically sound.

"They're Everywhere" is the title of an industrial film which Glenfield & Kennedy Limited have had prepared to show the care taken to turn out precisely dimensioned and trouble-free sluice valves. The production of the film was entrusted to Edward Cook of the Big Six Film Unit and in addition to showing actual valves in an almost endless variety of industrial application, the shots take one through a tour of the 40-acre works, explaining the manufacture of each component and the steps taken to achieve technical perfection.

Kent Dall Tube for Flow Measurement

An important advance in the field of flow measurement by means of a pressure differential has been made by George Kent Limited, London and Luton. Three devices for producing the required pressure differential are in common use today — the long venturi tube (known also as the "full" or "classical" tube), the short venturi tube (or venturi "orivent") and the orifice plate. George Kent Limited have now developed an entirely new device, known as the "Dall tube," which for a given differential is smaller and



lighter than the short venturi but is claimed to be superior even to the long venturi in differential-pressure recovery. This has not been done at the expense of accuracy, for the discharge coefficient of the Dall tube is stated to be stable and constant over its whole range.

The following comparison brings out the position clearly. Taking the upstream pressure as 1,000 units and the pressure differential applied to the measuring instrument as 100 units, the overall pressure loss for each of the four devices is as follows: long venturi 10 units, short venturi 16 units, orifice plate 60 units, and Dall tube 6 units. These values vary somewhat for other throat ratios, but they represent an average.

These characteristics can give rise to important savings, particularly where large pipelines are concerned. A meter requiring a certain differential pressure can work with a Dall tube with 30—50 per cent. less overall pressure loss than a long venturi tube. Alternatively, if the head loss is specified, the differential pressure generated by the Dall tube is almost twice or three times that generated by the long or short venturis respectively. This means that the operating power of the measuring instrument can be much higher, making for greater robustness and reliability.

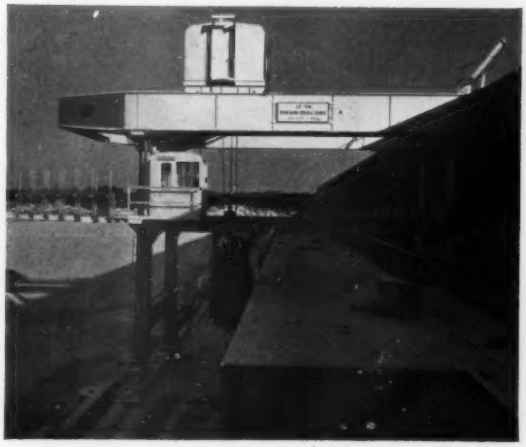
The Dall tube can also be used as a differential amplifier in combination with a large venturi tube (say upwards of 30 in.). A small bypass carrying the Dall tube is fitted between upstream and throat tappings on the venturi, and the greatly amplified head generated by the Dall tube is led to a second measuring instrument (the first being across the main tube), enabling readings to be taken down to about 1/20th or 1/30th of the maximum flow in the venturi. In this way the combination gives a wide flow range with low head loss.

The Dall tube is made of cast iron or steel, with a liner of brass or gunmetal, and consists of a short length of lead-in parallel pipe followed by two cones spaced apart at the throat, allowing a small gap. The larger end of both cones is appreciably smaller than the pipe bore. Both the cones are short and for the smaller sizes fully machined. Above about 24 in. pipe diameter only the centre portion of each cone is machined. Upstream pressure is taken out just before the larger end of the approach cone, while the throat tapping is within the chamber formed by the cone walls, in line with the gap between them. The Dall tube is much shorter than the venturi, averaging little more than one-and-a-half pipe diameters long, and is therefore correspondingly lighter and can be made as a complete unit.

For water-flow measurement the tappings should be at the side of horizontal or sloping mains. Tubes should be installed with at least 10 pipe diameters of straight length on the upstream side. No straight length of pipe is required downstream, and any form of control required should be fitted on this side. The tube should be placed so that it is constantly full and preferably under pressure. If desired, an inspection cover is fitted on Dall tubes over 12 in. in diameter.

Gantry Crane for Headworks

THE Dominion Bridge Company have recently supplied and erected a 25-ton electric gantry crane which is used on the headworks of a large scheme operated by the Hydro-Electric Power Commission of Ontario. It is used for handling trash racks, emergency stop logs and head gates, and incorporates an auxiliary high-speed hoist for lifting the trash rack cleaners. As may be seen from the accompanying



illustration, the trash rack sections and emergency gate logs are lifted by a follower, which hangs on the main hook. The follower is provided with hooks or latches at each end which automatically engage when lowered into the gate or other item to be lifted. The standard practice until now has necessitated the employment of a man to walk along with the crane on the deck of the dam, close to the gate slots, for the purpose of retrieving the rope which operates the lifting hooks. This man had necessarily to work close to slots over the running water, in somewhat hazardous conditions, especially in winter, when snow and ice conditions exist.

To meet the customer's specified requirements for the crane on this project, the Dominion Bridge Co. Ltd. originated a device whereby the rope is at all times kept taut; during the hoisting operation a torque motor drive connected to the latch system keeps a light tension on the rope so that it is automatically retrieved. When the time comes to release the latches the crane operator has only to press a button in his cabin for the full operating pull to be applied and the latches released.

Staffa 12 inch Hydraulic Pipe Bending Machine

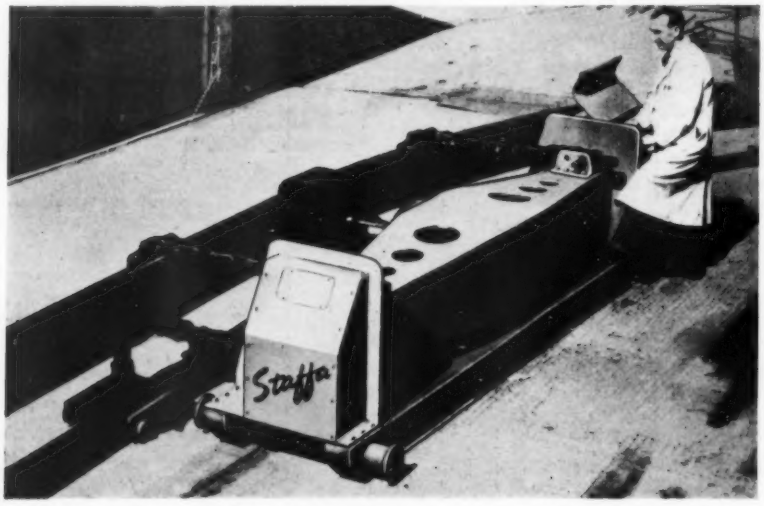
This machine, manufactured by Chamberlain Industries Limited, of Staffa Road, Leyton, London, E.10, is designed to bend solid-drawn steel pipe of 12¾ in. external diameter, with maximum wall thickness of ⅜ in., bending centres 8 ft., with a maximum angle of bend per stroke of 5 deg. It consists of a central former or saddle mounted on a hydraulically operated ram and moving between two end chain fixings. The ram unit, together with the end chain fixings, is contained in a box-section beam which can be rotated through 90 deg., enabling the pipe to be bent in a vertical or horizontal plane or at intermediate angles.

The main frame, which has an overall length of 13 ft. 2 in., with a depth of 2 ft. 6¾ in. and a height of 3 ft. 2 in., is of bolted and welded construction, the main members (two 8 in. by 5 in. rolled-steel joists) acting as skids on which the machine rests. One end of the frame is extended to form a platform on which the power unit is mounted. The bending beam, the overall length of which is 9 ft., is made up of ¾ in. plate welded to form a box section of maximum size at the centre and diminishing in two planes to form a 12 in. square box at each end. A heavy-duty trunnion is welded into place in each end of the beam, the trunnion at the power unit end being hollow to permit the passage of two flexible pipes to the ram, and two cast-steel chain-fixing brackets are bolted at each end of the beam to give bending centres of 8 ft.

The ram unit is tested with a 25 per cent. overload before installation in the machine. The ram is of high-tensile steel 5½ in. diameter, having a full stroke of 12 in. and developing a forward thrust of 85 tons. The maximum ram travel speed forward is approximately 3 in. per min., and the maximum return speed approximately 8 in. per min. The cylinder is made in one piece of cast steel, of 7 in. internal diameter and 11 in. external diameter, designed to withstand a working pressure of 5,000 lb. per sq. in. The ram nose is manufactured from high-tensile steel and designed to permit 5 deg. of movement of the former in any direction. This avoids kinking, as it provides for the groove in the former to be tangential with the tubing. The former, which is mounted directly on to the ram nose, is a one-piece steel casting with an overall length of approximately 1 ft. 1 in. A lifting ring is provided.

The pipe is retained in position by means of two specially constructed pipe chains, the links of which are made from high-tensile plate. The link pins are of 1¼ in. diameter high-tensile steel. Sufficient length of chain is provided to give 1 ft. adjustment at each end, and the chain will withstand a working load of 24½ tons. The chain-fixing brackets are provided with a double set of retaining lugs to hold two pins at each end of the chain, as an additional precaution against failure. A fixing pin can be provided to hold one end of the chain permanently in position.

The power unit is mounted on a ½ in. thick baseplate and is completely housed in a small frame constructed of rolled-steel sections. The frame is specially strengthened in places that are likely to come into contact with the pipe during bending. The unit consists of:—



1. Either a J.A.P. forced-draught air-cooled governor-controlled petrol engine, developing approximately 5 b.h.p. at 1,800 r.p.m., or a 6 h.p. electric motor.

2. A Beacham two-stage hydraulic pump driven by the motor through a vee-belt reduction drive. The delivery is controlled by a handwheel giving a variation between zero and 120 cu. in. per minute, approximately. This enables the ram travel speed to be adjusted from zero to approximately 3 in. per minute maximum.

3. A sheet-metal petrol tank mounted above the pump.

4. A control panel, consisting of a ram control handle with three positions (forward—stop—return), a hand-control spring-release valve enabling pressure to be adjusted from zero to a maximum, a delivery control handle, and a 4 in. pressure gauge graduated in lb. per sq. in., and also direct thrust in tons. A lock is provided for retaining the delivery handle in any one position. The control panel is built into the main housing and a detachable cover is provided for use when transporting the machine.

The flexible pipes in the hydraulic circuit are of synthetic-rubber construction, with internal wire braiding between the two rubber sections to withstand a working pressure of 5,000 lb. per sq. in.

The actual working time for cold and unloaded bends in 12 in. bore tubing is cut to one 90 deg. bend per hour, as against two per day by the conventional "Jimcrow" method. A one-man crew is all that is required. This machine was originally designed to fit the requirements of a large oil company and its compact and narrow design renders it especially suitable for the bending of tube to large sweeps of about 25 ft. in situ, in the actual pipe trench. The machine weighs 2 tons 9 cwt.

Abstracts from the World Technical Press

Harnessing Floods to the Stabilisation of Operating Heads

In hydro-electric plants working under a medium or low head there is, at flood periods, a considerable risk of the power house being submerged by the rise of the downstream water level. The provision of emergency turbines running at flood periods only would prove uneconomical, and the real problem to be tackled consists in recovering the loss in head by using the flow of floodwater to lower the downstream level immediately at the turbine outlet or to increase the depression in the diffuser of the turbine. Under the not quite appropriate term of "head boosters" various solutions have been suggested such as Herschell's and Freeman's devices, acting directly on the diffuser of the turbine, or lateral sluices in the dam, working on the ejector principle; the advantage of these systems is, however, minimised by the high construction costs involved.

At the small automatic Faux-la-Montagne plant, attached to the Vienne and Maulde development scheme, upstream from Peyrat-le-Château, the French Regional Board responsible aims not only at preventing the plant from being submerged at flood periods, but also at stabilising the head at a constant maximum. After extensive model tests effected at the Chatou National Laboratory, the solution ultimately adopted consisted in connecting the tailrace, about 60 m. downstream from the plant, to the very steep spillway so as to induce a high-speed flow of the floodwater, and to create a jet effect at the end of the tail race. This solution, which produces the greatest depression downstream from the tailrace, clearly appears from the appended diagram Fig. 1, which shows in plan and longitudinal elevation the confluence of the tailrace with the spillway. As can be seen, the floor of the tailrace has been kept at 668.25 m., except at its downstream end, where a double step (667.55 and 667.10) produces the critical depth exactly at the junction of the tailrace with the spillway at periods of high water and, on the other hand, ensure an easier superposition of the two water layers. Moreover, the spillway, which has a gradient of 18.6 per cent., gradually widens from 1.50 to 3.50 over a length of 50 m. Finally, the junction acts as a stilling pool; length and depth of this pool are minimal, and the dowstream sill is at 668.10 m.

This arrangement enables the operating head to be kept almost constant at flood periods without involving any increase in construction costs.

The water levels in the tailrace and at its junction with the spillway (Fig. 2) show the jet effect produced by the floodwater rushing down in the latter at a rate of 6 and 12 cu. m. per sec. respectively; this jet effect is noticeable as soon as the spillway discharge reaches 5 cu. m. per sec.

In the case instanced of a medium-head plant, the relative gain in power is necessarily low, but the model tests carried out at the Chatou Laboratory appear to justify the adoption of "head boosters" in

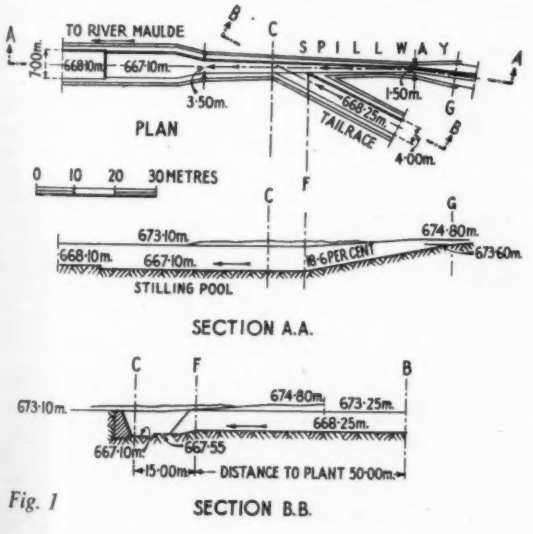
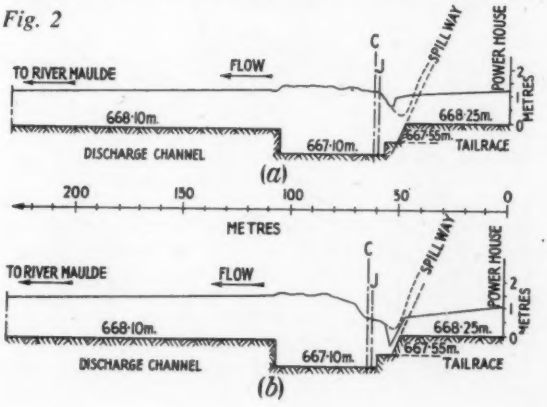


Fig. 1

Fig. 2



low-head plants. With this end in view, the author concludes with a short survey of the latest types of run-of-river plants, pier power units and submersible plants. Further exhaustive model tests are to be carried out in this connection at the Chatou Laboratory. (G. Marquenet, *La Houille Blanche*, Vol. 6, special issue A, May 1951, p. 268, 11 pp., 19 ff.)

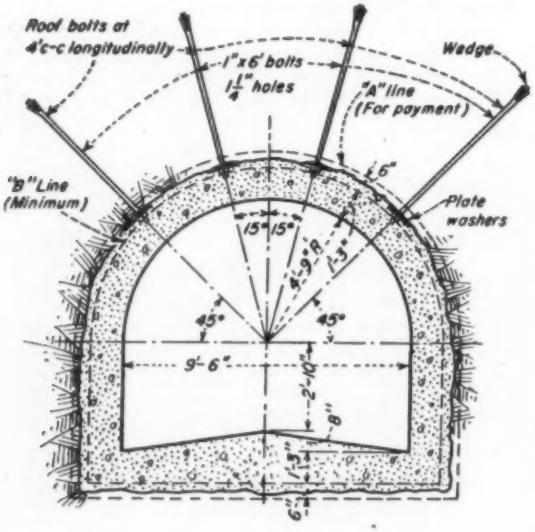
Work on Flatiron Plant Under Way

The Bureau of Reclamation awarded on April 11 the contract to build the Flatiron power and pumping plant, dam, afterbay, and ancillary works. This feature of the Colorado-Big Thompson scheme will have one of the highest heads on any reclamation project. From Bald Mountain tunnel the water will fall 1,055 ft. to the dual-purpose plant which will generate hydro-electric power, and also pump irrigation water into Carter lake for the benefit of northeastern Colorado districts. An unusual feature of this plant is the use of Francis turbines; heretofore Pelton wheels have been used almost exclusively on heads exceeding 1,000 ft.

During slack periods of the day, when the demand for irrigation water has been met, the 10,000 kW unit will be thrown into reverse and, instead of pumping water into Carter lake, will draw upon the reserve storage to generate power for peak-load demands. This is the second time in reclamation history that a pumping or generating unit has been called upon to serve in a dual rôle; the other similar installation is located in Utah on the Strawberry Valley project, which the Bureau started constructing in 1906. (*The Reclamation Era*, Vol. 37, No. 6, June 1951, p. 124)

Roof Bolting in a Diversion Tunnel

The 11 ft. × 12 ft. by 654 ft. diversion tunnel at the Keyhole Dam, Wyoming, was driven without using any protective lagging or bracing in spite of the fact that the surrounding sandstone contained open seams and was subject to slacking when exposed to air. In this instance the contractor resorted to a method now commonly used in coal mining to hold cracked formations. The roof bolts, 1 in. diameter, whose location was left to the judgment of the tunnel foreman, were power driven into 1½ in. holes drilled radially to the axis of the tunnel to a depth of 4 in. less than bolt length. All roof bolts were 6 ft. long, except 27 bolts 8 ft. 4 in. long used horizontally at the portals. As shown in the accompanying drawing a steel wedge was set into the slotted end of each bolt; when this wedge hit the bottom of the drilled hole, the slot spread, thus providing anchorage. Plate washers 8 × 8 × ⅜ in., placed under a nut on the exposed end of the bolts, held the faulted rock safely in place. The nuts were tightened with an air wrench and a handratchet wrench. (*Engineering News-Record*, Vol. 146, No. 20, p. 30, 2 pp., 5 ff.)



Quebec Power Project

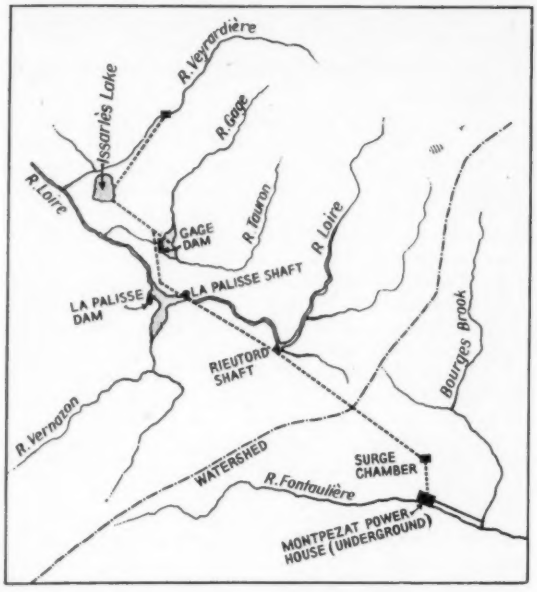
Having developed the outlet of Lake St. John, Saguenay River, the Aluminium Company of Canada have now moved up into a tributary of that lake to increase the power supply for its Armida works which serve Canadian and American defence needs. The Company has awarded to Fraser-Brace Engineering Company, of Montreal, the contract for the construction of a 400,000 h.p. hydro-electric development at Devil's Falls, Peribonka River, near Lake St. John. (*Engineering News-Record," Vol. 145, No. 20, November 16, 1950, p. 24, col. 1.*)

The Issarles-Montpezat Scheme

Of the several French development schemes striding over the tributary watershed of two seas (Atlantic and Mediterranean), the Issarlés-Montpezat plant in the Ardèche Département, is the only one which has so far reached the actual construction stage. In this project, water is drawn from the Loire and a few of its tributaries in the Gerbierdes-Jones massif (Cévennes) for diversion to the Fontaulière, a tributary of the Ardèche in the Rhône basin. This scheme will, at first, comprise two main dams, one near La Palisse on the Loire, 170 m. in length and 60 m. in height, the other, 115 m. in length, 47 m. in height, at the spot called Moulin-de-Peyron, slightly downstream from the confluence of two Loire tributaries, viz., Gage and Tauron.

In addition, a water intake, consisting of a dam 66 m. in length by 16 m. in height, is being built on the Veyrardière to divert its course to the Issarlès lake. A shaft, about 60 m. deep, sunk near the Issarlès lake, will enable water to be drawn from this lake between 1,003 and 960 m. The natural water level of the lake is at 997 m. The utilisable volume of water between 1,003 and 960 represents a reserve of about 32 M. cu. m. The water from the Veyrardière will flow through the aeration conduits of this shaft, the lake, 108 m. deep, playing the rôle of a natural regulation reservoir.

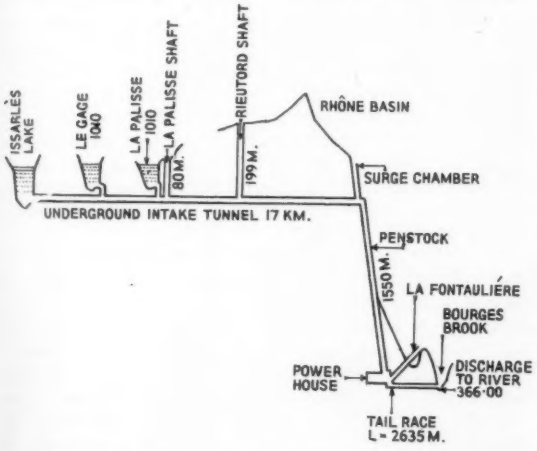
Starting below the bottom of the Issarlès lake, and connecting on its way with the Gage and La Palisse reservoirs, a tunnel, 17 km. long, will convey the water to the penstocks; the first four kilometres of this tunnel, 3 m. in diameter (Issarlès-La Palisse section) will ensure alternately the filling of the lake and the drawing off of its water to the power house.



Owing to the importance of the Issarlès lake as a popular resort for tourists, Electricité de France (the French Electricity Authority) was requested to maintain the water at a determined level during the summer months.

The 13 km. long section of the tunnel below the La Palisse dam will increase in section from 3·20 to 3·60 m. diameter.

The driving of the tunnel was started through two access galleries (one 343 m. long at the Gage, and



the other, 227 m., at Burz), and two shafts 5·80 m. in diameter, one 80 m. deep at La Palisse, the other, 199 m., at Rieutord.

Following the intake tunnel, the 1,550 m. long penstock begins below a surge chamber erected at the top of the Suc de Montasset; it is 2·60 m. in diameter at the top and 2·30 m. at the bottom, and leads to the underground power house excavated at Champagne, near Montpezat, 60 m. below the bed of the Fontaulière. A shaft fitted with lifts for personnel and material will provide access to the power house. Downstream from the power house a discharge tunnel will convey the water to the Fontaulière at a distance of 2,635 m. from the turbines.

This installation affects a catchment area of about 200 sq. km. Thanks to the Isslarès lake and the dams on the Loire and tributaries the useful reserve stored will be about 45 M. cu. m. The provided discharge of 22 cu. m. per sec. will actuate two horizontal-shaft sets of 81,000 h.p. each consisting of a 15,000 V alternator flanked on either side by a two-jet Pelton wheel running at 428 r.p.m.

The aggregate work will involve a total of 380,000 cu. m. of excavations, of which 320,000 cu. m. will be underground, and 25,000 cu. m. in shafts. The material required is estimated at 110,000 cu. m. of concrete (40,000 tons of cement and 2,000 tons of steel), 9,000 cu. m. of timber, 700 tons of explosives, and 9,100 tons of steel sections and other metals. The plant is to be commissioned in 1955, and it is expected that the 325 M. kWh it will produce will permit to dispense with the importation of 250,000 tons of coal per annum, resulting in an economy of 2,000 M. Fr. (Roger Seive, *Equipement Mécanique des Mines*, Carrieres et Grandes Entreprises, Vol. 29, No. 259, May 1951, p. 19, 2 pp., 2 ff.)

Money-Saving Methods at Woodruff Dam

Jim Woodruff dam is being built across the Apalachicola river just below the confluence of the Flint and Chattahoochee rivers, near Chattahoochee, Florida; its main purposes are to provide a 9 × 100 ft. navigation channel on the lower Flint and Chattahoochee, and power generation. The structure will create a lake covering 37,500 acres, which will be developed for recreational purposes; the maximum head will be 33 ft.

The principal components of the dam are, from east to west: (1) a 3,310 ft. earthfill dike, now completed, on the west end of which will be the switch yard; (2) a power house with three 10,000 kW generators; (3) a 760 ft. long gated spillway section with sixteen 40 × 30·5 ft. vertical-lift gates; (4) a navigation lock, and (5) a 1,634 ft. long concrete overflow section. The power house and the spillway section, as well as the mound for the switch yard will be built under future contracts; (4) and (5), which are in course of construction, confronted the contractor with awkward problems which have been solved with great ingenuity.

In order to overcome difficult foundation conditions, cut costs on rock excavation, and speed up concreting, the contractor devised new types of equipment or adapted equipment previously used in other industries. He designed a 25 ton trailer for hauling concrete from the mixing plant to the job; he used a shale saw, cutting in the porous limestone foundation slots 6 in. wide by 5½ ft. deep, instead of line drilling prior to blasting, and, in co-operation with the Corps of Engineers, he developed high-pressure water jets for green cutting concrete surfaces to get a good bond at construction joints and for cleaning the surfaces prior to placing the next lift.

A distinctive feature of the trailers is that they have space for carrying three 4 cu. yd. buckets at a time but usually carry only two loaded buckets out

to the site, leaving a space for an empty bucket, and return to the mixing plant with two empties. Upon arriving at the site a crane places an empty bucket on the trailer before picking up a loaded bucket which, as soon as empty, is returned to the trailer. Immediately after the crane has lifted the second loaded bucket, the trailer is hauled back to the mixing plant for another load.

Not only did these methods, which are described in detail in the article, bring about a considerable reduction in construction costs and speed up concreting, but a conspicuous safety record was achieved. (Frederick S. Merritt, Associate Editor, *Engineering News-Record*, Vol. 146, No. 24, May 31, 1951, p. 33, 3 pp., 6 ff.)

Digest of this Issue

Sommaire

La Houille Blanche au Canada (page 294).

Cette étude des ressources du Canada en houille blanche est basée sur un rapport de la Water Resources Division du Department of Resources and Development; elle montre comment la puissance hydro-électrique exerce déjà, bien que partiellement exploitée seulement, une influence marquée sur l'économie du pays. La capacité des usines installées s'élève aujourd'hui à plus de 12,5 millions h.p., dont 962 275 ont été ajoutés en 1950. Sur la base d'un fonctionnement continu et d'un rendement de 80%, les ressources disponibles sont évaluées à 43 millions h.p.

Une analyse de la distribution par provinces des ressources potentielles et exploitées du Canada montre que, à l'exception de l'ile du Prince Edouard qui est assez dépourvue, la richesse hydro-électrique est dans l'ensemble bien répartie. Les progrès accomplis en 1950 ont été remarquables, dans l'Ontario en particulier, ainsi qu'en Colombie Britannique. Suivant le programme actuel le taux d'accroissement de la capacité sera d'environ 600 000 h.p. par an pendant plusieurs années.

La Houille Bleue (page 302).

L'auteur justifie son affirmation que l'énergie éolienne peut apporter à un réseau electrique étendu une contribution importante, à un prix relativement bas. En raison des très grandes variations du vent, il est indispensable de pourvoir à l'emmagasinage de l'énergie; le moyen le plus simple est de constituer une réserve d'eau, annexe de la station éolienne.

Etudiant le problème de l'apport éolien à un large réseau, l'auteur mentionne les facteurs durée et capacité, tous deux basés sur la statistique mensuelle, et qui doivent servir à l'evaluation de la puissance des stations projetées. En ce qui concerne le type d'aéro-generatrice, il estime que le moulinet à claire-voie, dont le taux de solidité en bout de pale est inferieur à 10%, donne les meilleurs résultats, avec une vitesse de bout de pale au moins égale à la moitié de la vitesse du son.

Compendio de esta Edición

Recursos de Energía Hidráulica en el Canadá (página 294).

Este estudio de los recursos de energía eléctrica canadiense ha sido basado sobre un informe publicado por la "Water Resources Division" del Departamento de Recursos y Desarrollos, y pone de manifiesto que la energía hidroeléctrica, si bien tan sólo ha sido parcialmente desarrollada, está ejerciendo una influencia bien definida en el bienestar económico del país. La capacidad de las instalaciones ya existentes en la actualidad asciende a más de 12.1/2 millones de H.P. y durante el año 1950, constituyendo el año bajo revista, se añadieron 962.275 H.P. Se calcula que la energía disponible durante 24 horas a base de una eficiencia del 80% asciende a casi 43 millones de H.P.

Se reproduce un análisis de la distribución provincial de la energía eléctrica potencial y desarrollada, y en conjunto se pone de manifiesto que los recursos de importancia están bien distribuídos. La única excepción es la Isla Prince Edward, donde los recursos son pequeños.

Los progresos realizados durante el año 1950 han sido de naturaleza saliente y de manera especial Ontario ha añadido instalaciones ascendiendo a una capacidad adicional de un millón de H.P. y también se están realizando progresos satisfactorios en British Columbia. Los programas preparados en el presente indican que la capacidad aumentará a razón de unos 600.000 H.P. por año por espacio de algunos años a venir.

Energía Generada por el Viento (página 302).

El autor establece la reivindicación de que la energía generada por el viento, al ser utilizada como un medio auxiliar en una espaciosa red de distribución eléctrica, puede contribuir a la generación de energía de un costo relativamente bajo. Debido a las cualidades grandemente variables del viento en la mayor parte de regiones del mundo es necesario establecer algún medio para acumular la energía derivada de este elemento y el método más fácil para el logro de este objeto consiste en establecer almacenamientos hidráulicos, conjuntamente con instalaciones de viento generadoras de energía.

En este artículo se discute el establecimiento de las posibilidades de la energía generada por el viento en una red de grandes proporciones y con referencia a este punto el autor hace mención de un factor de duración y de un factor de capacidad, ambos basados sobre cifras mensuales, y la clasificación de una instalación que pueda proyectarse debería ser determinada con relación a los factores referidos. Se discute el asunto relativo al control y respecto al diseño del generador aéreo el autor considera que la rueda de tipo abierto con una relación de solidez de menos del 10% cerca de la punta debería ser la más efectiva, con una velocidad periférica representando por lo menos una mitad de la velocidad del sonido.

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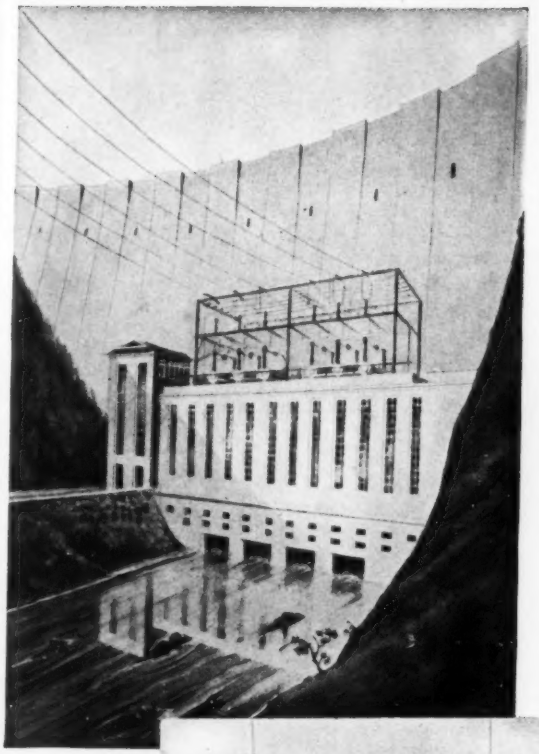
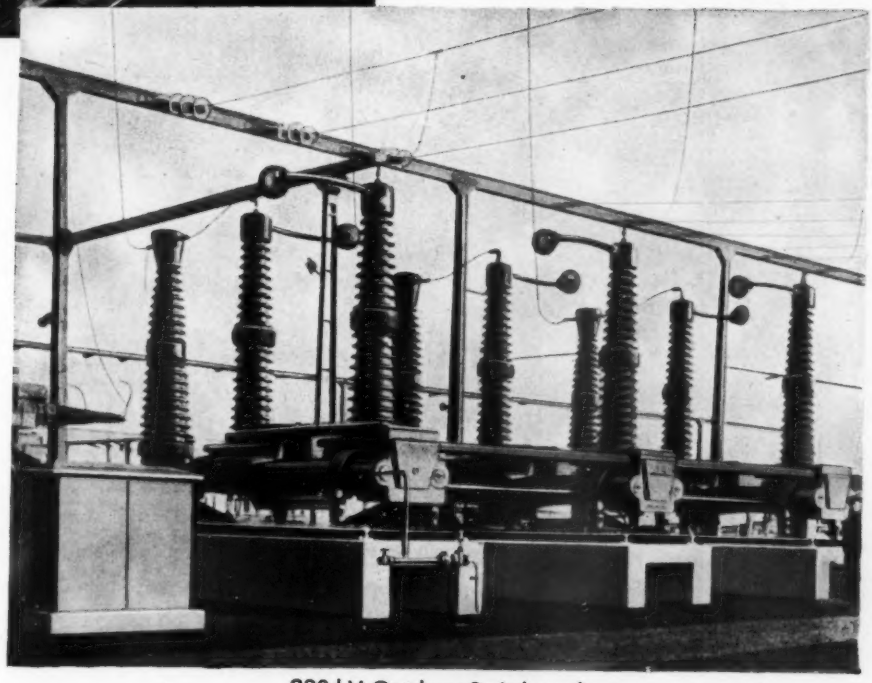


AEG

Outdoor and Indoor High Tension Switchgear for Hydro-Electric Power



220 kV Outdoor Switchyard

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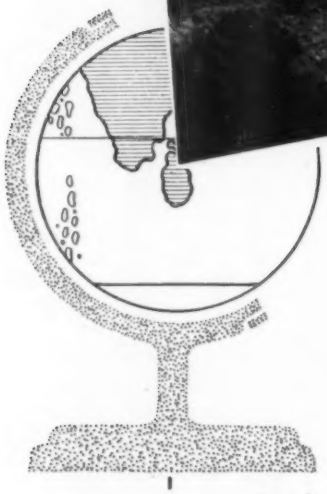
CEYLON HYDRO-ELECTRIC SCHEME



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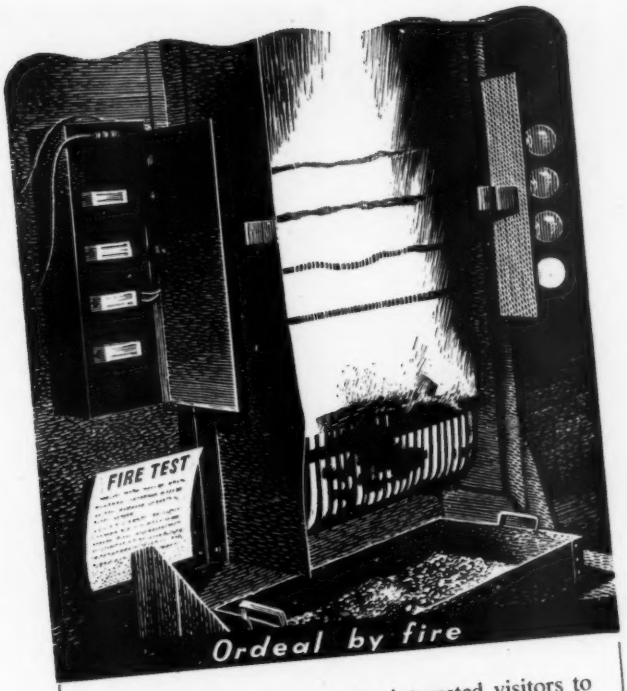

Ordeal by fire

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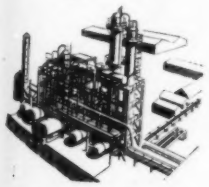

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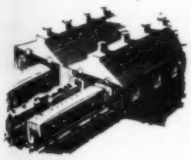

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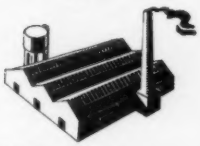

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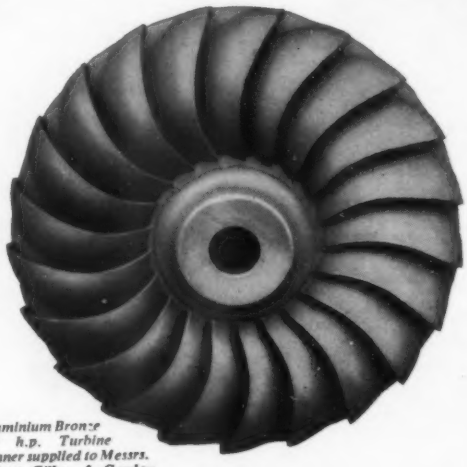

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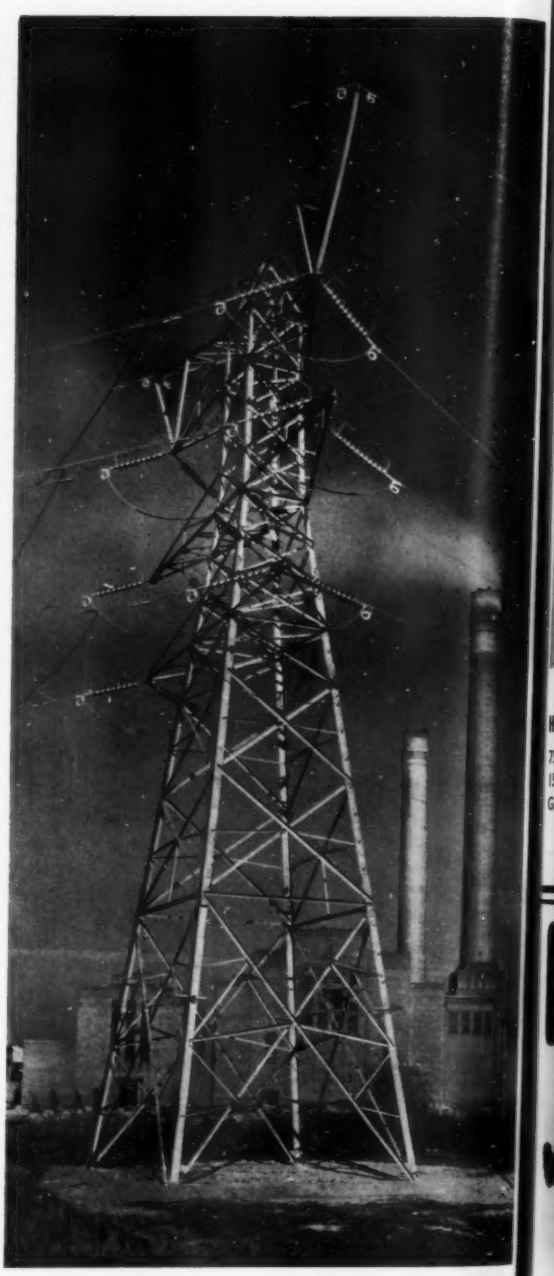

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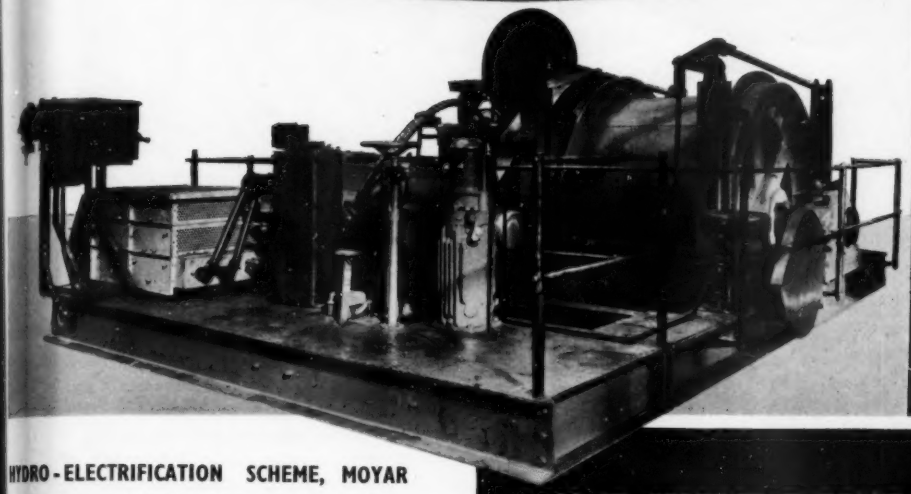

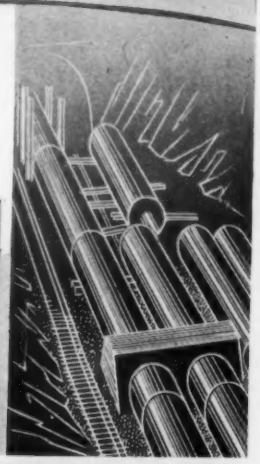

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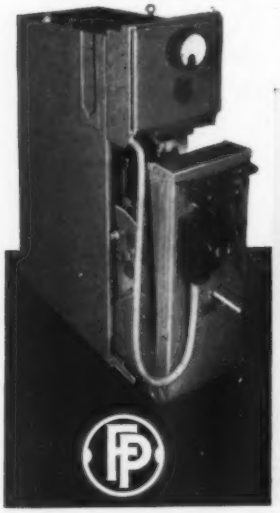
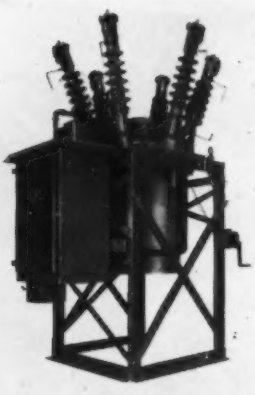


Below right: Type ROP 54 oil circuit breaker for outdoor service up to 66 kV.



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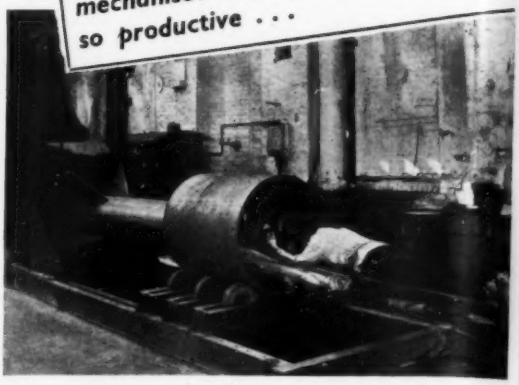

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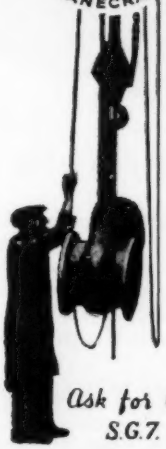

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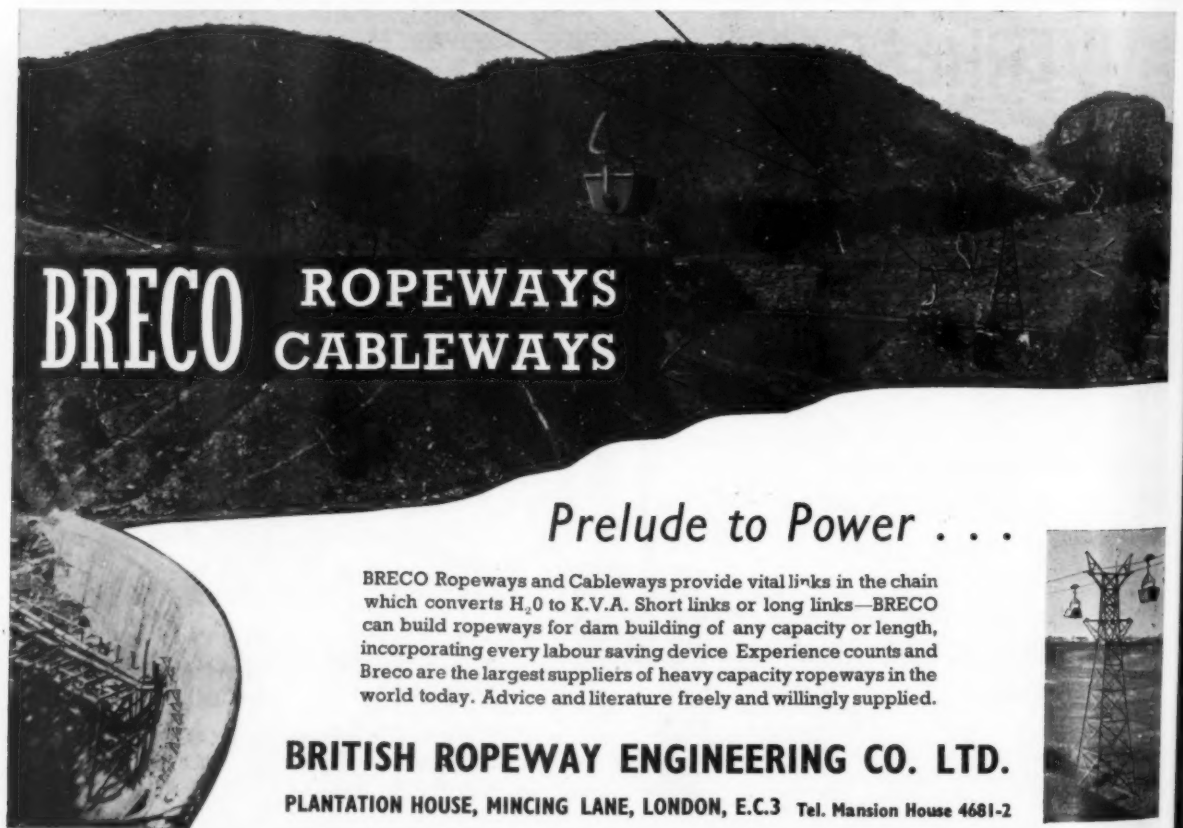

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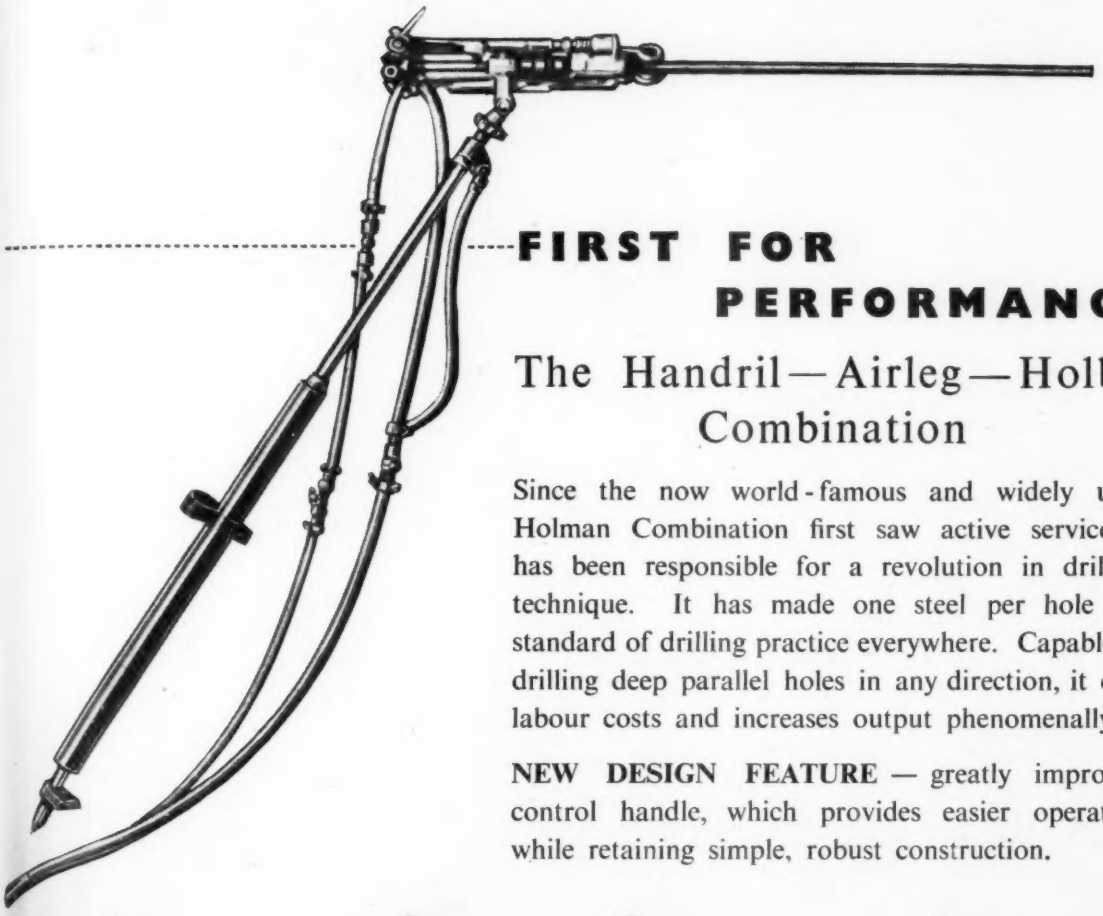

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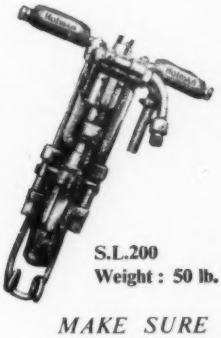

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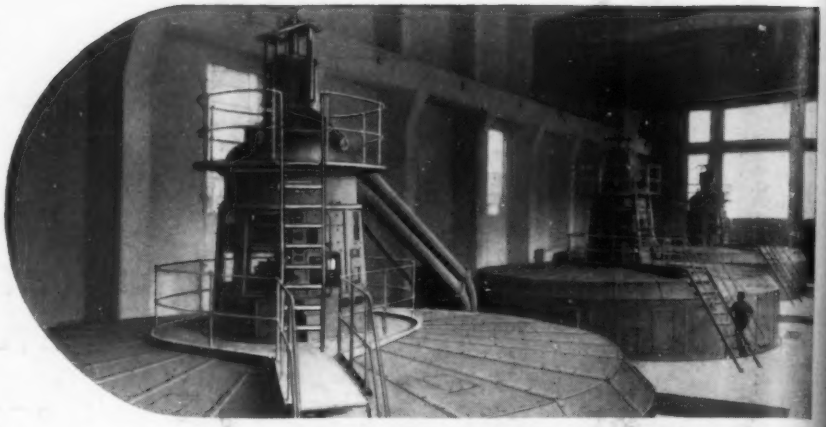

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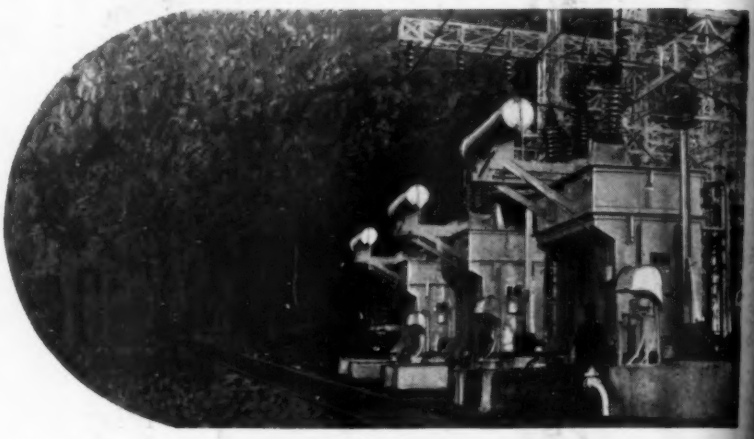

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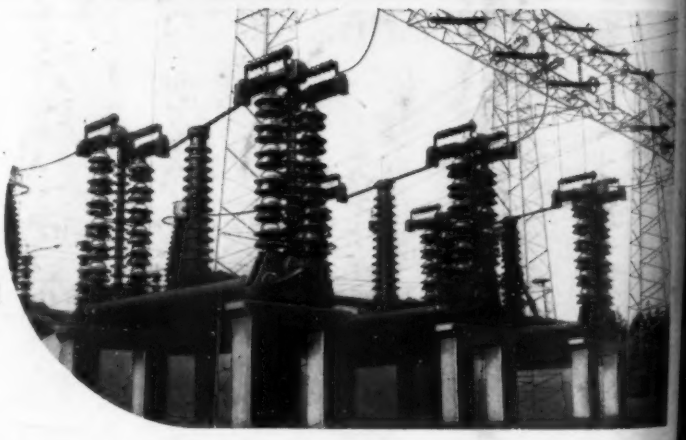

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